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RULE-BASED EXPERT SYSTEMS
IN THE COMMAND ESTIMATE:
AN OPERATIONAL PERSPECTIVE

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

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B.S., East Central Oklahoma State University, 1977

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ABSTRACT

RULE-BASED EXPERT SYSTEMS IN THE COMMAND ESTIMATE: AN OPERATIONAL PERSPECTIVE, by Major Timothy R. Puckett, USA, 221 pages.

This study is an anlaysis of how the branch of artificial intelligence known as rule-based expert systems can be used to assist in the performance of the command estimate as prescribed in Command and General Staff College Student Text 100-9, The Command Estimate.

Current command and control systems are analyzed to determine why battlefield information management is not successful. Trends in civilian decision aids for corporate executives are introduced and contrasted with military requirements. The capabilities of rule-based systems are discussed and a base line for their use in the command estimate is introduced.

Observations of the command estimate made by the Center for Army Lessons Learned (CALL) and the Army Research Institute for the Behavioral and Social Sciences (ARI) are analyzed to determine areas of the command estimate that can benefit from assistance with rule-based systems.

A detailed examination of the flow of information through the command estimate process is conducted using techniques of systems analysis. Additionally, the Intelligence Preparation of the Battlefield (IPB) is analyzed using the same methodology. This study of the information flows and the types of information managed by each process indicates areas that can be enhanced with assistance by rule-based systems.

The study concludes that rule-based systems can be used to automate the IPB process and significantly contribute to portions of the command estimate. The role these systems can play is best described as a staff aid. Functions would include expression and dissemination of the commander's intent, creation of planning time lines and synchronization matrices, standardization of mission statements, performance of the IPB, assistance and maintenance of task organizations, tracking of critical events, and creation and dissemination of warning orders.

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CHAPTER 1

INTRODUCTION

The estimate of the situation has been the bedrock for military decision making in the United States Army since the turn of the century.[1] When used to assist the commander and staff as they plan and conduct combat operations it is referred to as the command estimate. This cyclic process has withstood the tests of time and combat. It is a highly refined procedure. Until now, the command estimate has been omitted from the technology envelope of the automation revolution that has swept the modern battlefield. However, the maturation of the branch of computer science known as artificial intelligence (AI) raises the question of whether the command estimate process can be automated in future battlefield command and control (C2) systems.

Although the command estimate appears to be rigidly structured, it is not a simple mechanical process and is dependent upon continuous input of information. For the process to be successful, it must rely on the constant interplay of the commander's experience,

knowledge, and evaluation of the information continuously provided by the staff. In effect, the command estimate is as much military art as it is military science.

The current generations of automated command and control systems are complex in physical architecture but do little more than simple processing of tabulated information. The amount of information that these systems can sort, sift, filter, merge, collate, or rank has surpassed the human management threshold and may inundate the commander with the sheer mass and volume of data produced. Indeed, the tremendous amount of unprocessed data these systems present to the commander may be a hindrance to making smart battlefield decisions.

The civilian sector is beginning to answer this dilemma by the introduction of artificial intelligence within the framework of control systems.[2] A specific area of promise is that of rule-based expert systems. Based on a structure of rules defined by human "experts", these systems can process mundane and trivial information and appear to make decisions. These decisions are nothing more than the adherence to a set of human responses predefined for specific situations. This frees the human-decision maker from distraction and allows more effort to be concentrated on the task at hand. These redefined

business-decision and control systems do not simply process data; they manage and leverage the information into a tangible asset.

The use of rule-based expert systems in corresponding civilian decision-support systems indicates their possible use in the military decision process. However, due to the dynamics of combat operations and the tenuous nature of much of the information involved, the use of such AI techniques is still uncertain.

The command estimate is the definitive example of the military decision cycle. Figure 1 represents this process as depicted in U.S. Army Command and General Staff College Student Text 100-9. As shown, the command estimate appears to be highly procedural with well delineated steps, start points, and end points.[3] However, its use depends on many human factors including a keen knowledge of tactics and experience levels. Additionally, the fluid and constantly changing reality that represents the modern battlefield complicates the proposition of artificial intelligence-based C2 systems.

Due to the complexity and dynamics of military decision-making, it is not feasible to simply adapt an existing civilian rule-based expert system to fit the command estimate model. A significant problem is that such a system designed to work in one well-defined situation may be faced with considerably different

THE COMMAND ESTIMATE

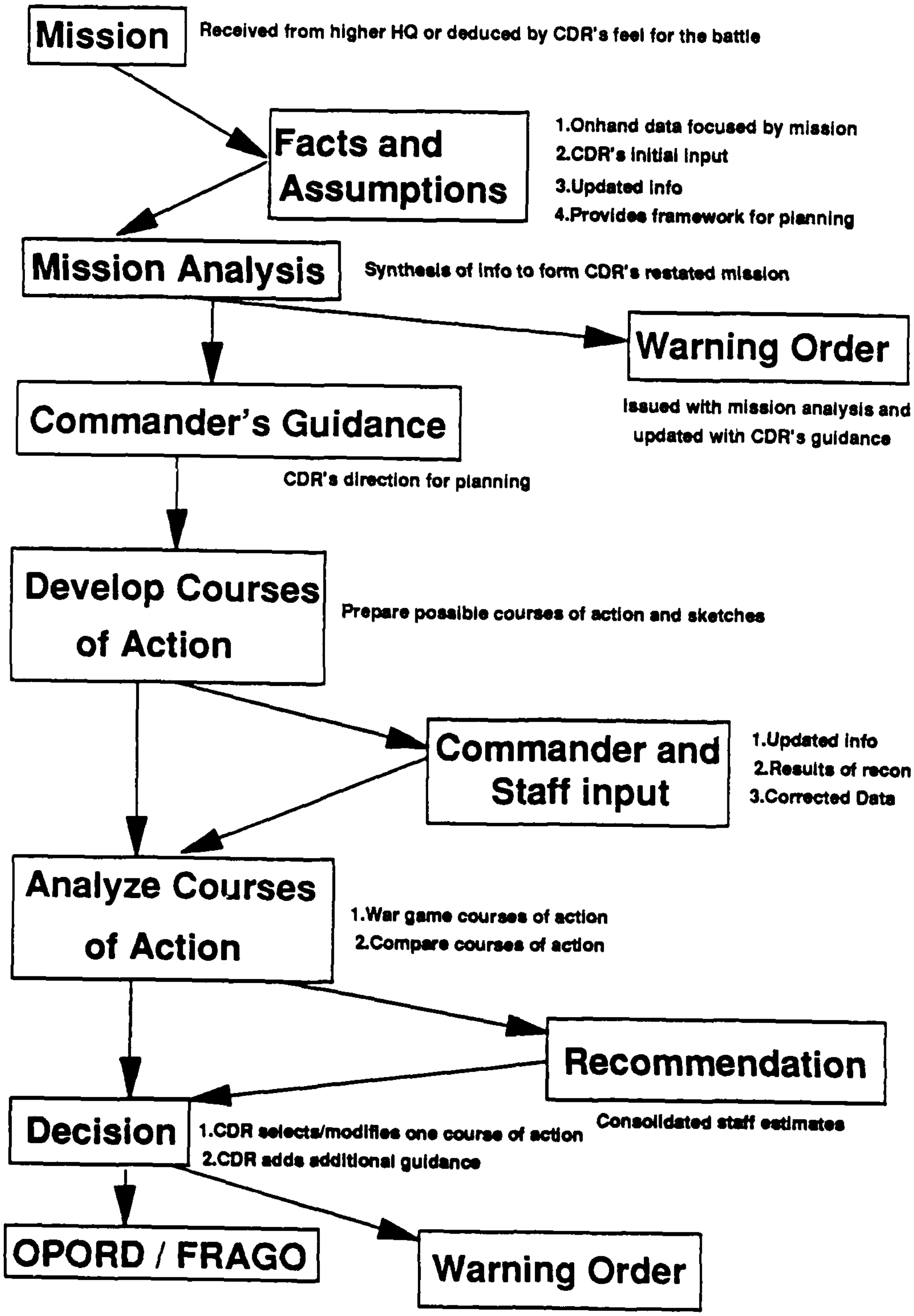

Figure 1.

environments during combat operation. Additionally, no two units in the Army operate in exactly the same way. This results in the condition that a rule-based expert system built on a single decision model may not be applicable for every unit unless it can be tailored for the particular unit based on the way it operates as defined by resident experts (i.e., commanders and their staffs). A third feature is that under the pressures of combat, the command estimate process may assume an entirely different shape than as taught in the classroom environment. These factors indicate that there are considerable challenges in the implementation of an AI-based C2 system.

Background

The Maneuver Control System (MCS) is the Army's first attempt to emplace a comprehensive automated C2 information processing system across the tactical spectrum. Although it is an impressive effort, the strength of MCS is found in its communications ability rather than in the computer system. MCS does little more than simple data base manipulation. This provides limited utility until the information is further interpreted and refined by the commander and staffs. Most importantly, because of the data processing power automation has given

MCS, it is capable of overloading the commander and staff with information. Due to the nature of military operations, the occurrences of this overload will be at the times when the most critical decisions have to be made.

Basic limitations in the sophistication of the software constrain the way MCS can present information for interpretation. The human process of filtering this information for application in the decision cycle adds a significant amount of time. By the time this data is interpreted, it is either too old or has become overcome by events and is of no use in the battlefield commander's decision cycle. It is obvious this infusion of dated, incomplete, and inaccurate information has the potential for disastrous or catastrophic implications in regard to battlefield decisions.

In its present form, MCS does not provide the commander with any decision-aids. MCS does have the potential to provide an embryonic platform for efforts to implement artificial intelligence aids within military decision making and command and control. The focus for any effort in this area will be provided by the Combined Arms Center Future Battle Lab, Fort Leavenworth, Kansas.

The key to success for any future C2 systems is high fidelity implementation of the command estimate. A concentrated effort is currently focused on the use of AI

in the development of the future generation of automated C2 systems. This effort includes the possible use of AI in the command estimate process. However, a preliminary review of literature indicates that this research is being driven by computer scientists without apparent regard to the operational needs of Army commanders and their staffs. This may be attributed to the confusion of where military science ends and military art begins.

Purpose of the Thesis

The purpose of this thesis is to establish a militarily operational viewpoint of using rule-based expert systems in an automated command estimate.

Assumptions

1. Due to the relative recent emergence of artificial intelligence from the academic environment to solve real world problems, proposals for AI-based implementation of the command estimate will have originated from other than an Army source.

2. There exists a need to evaluate the implementation of rule-based expert systems in the command estimate from a purely military perspective.

3. There are qualified experts to serve as the subject matter experts who can quantify the necessary

knowledge base to implement rule-based expert systems in portions of the command estimate.

4. Software techniques and capabilities for the development of AI-based C2 systems exist and are available within present technology.

5. The most current literature will be found in periodicals. The focus of this information will not be restricted to military applications and a degree of inference will be taken to equate the civilian sector experience with military requirements.

Definition of Terms

Artificial Intelligence: A branch of computer science in which computer-based solutions to complex problems are derived through the application of processes that are analogous to human reasoning.[4]

ATCCS: Army Tactical Command and Control System. The command and control system utilized by all tactical echelons up through corps. ATCCS includes the organization, facilities, and procedures through which the commander plans, directs, controls, and coordinates operations.[5]

Command and control (C2): The process through which the activities of military forces are directed, coordinated, and controlled to accomplish the mission. This process encompasses the personnel, equipment,

communications, facilities, and procedures necessary to gather and analyze information, to plan tasks, to issue instructions, and to supervise the execution of operations.[6]

<u>Command and control system</u>: The totality of automation, communications, and procedures used to gather information, process the information, develop operational plans, generate military orders, and convey these orders to subordinate elements to execute a mission.

<u>Command estimate</u>: The process used by military commanders and their staff that focuses on essential facts and necessary assumptions to make decisions that will lead to success on the battlefield.[7]

<u>Estimate of the situation</u>: In the military decision making process, the collection and analysis of relevant information for developing, within the time limits and available information, the most effective solution to a problem.[8]

<u>Expert Systems</u>: A sub-field of artificial intelligence in which the computer programs follow rules established by a human expert in a specific problem domain.[9]

<u>Maneuver control system (MCS)</u>: A command and control system that focuses on the tactical execution of

war. Currently, MCS is in the form of an automated system based on a collection of data bases and attendant communications facilities to disseminate information.

Rule-based: A technique of AI in which a decision is predicated on satisfying an established set of rules governing any problem solution.

Subject Matter Expert (SME): A human expert in a particular field or problem domain from which the procedures for solving a particular problem are taken.

Limitations

1. The scope of this thesis will not allow a detailed history or explanation of artificial intelligence or expert systems.

2. The use of the term artificial intelligence within this thesis is used interchangeably with the term, rule-based expert systems. I recognize that artificial intelligence is a broad and ever expanding domain. Furthermore, expert systems is a growing subset of artificial intelligence with many variations and nuances in addition to rule-based systems.

Delimitations

1. This study will not produce computer language code or any rule-based expert system models.

2. Classified subjects will not be addressed.

3. The rule-based expert systems recommended within this thesis are meant to be aids to the commander's staff officers. These systems will not replace the function of any soldiers but will serve as staff-aids to improve the information flow through the staff to provide the commander with the best information upon which to make decisions.

4. Unless otherwise stated, whenever the masculine gender is used, both men and women are included.

Significance of the Study

This thesis will provide an Army perspective of the operational needs of rule-based expert systems within the command estimate. It will provide scope and direction of future Army automated command and control systems that incorporate artificial intelligence in the military decision process.

Thesis Outline

Chapter 2: Review of Literature. The branch of artificial intelligence known as rule-based expert systems is described in respect to military applications. The concept of battlefield information management is then examined and explained to support the need of managing and

controlling information in a tactical environment. Finally, the methods used in the civilian business community to control important information is introduced.

Chapter 3: Research Methodology. The use of hypertext, electronic mail, personal and telephonic interviews with subject matter experts and a literature review served as the primary research vehicles for this thesis. The techniques used to implement these methods are analyzed and discussed in this chapter.

Chapter 4: The Need for Rule-Based Expert Systems in Command and Control. This chapter establishes a baseline argument for the need of automation in modern command and control. In addition, this chapter addresses the advantages of applying rule-based expert systems to portions of the command estimate.

Chapter 5: Observations of the Command Estimate. This chapter analyzes formal observations made into the performance of the command estimate by the Center for Army Lessons Learned and the Army Research Institute for the Behavioral and Social Sciences. Additionally, it discusses the command estimate as viewed from several functional area experts within the Center for Army Tactics. In conjunction with the examination of these discussions, recommendations are made to incorporate rule-based systems to assist the implementation of the command estimate.

Chapter 6: Analytical Decomposition of the Command Estimate. This chapter examines the command estimate process from a systems analysis point of view. It discusses operational Army requirements combined with an analysis of those portions of the process that can best be performed by an AI-based system and those that are best done with the current manual technology.

Chapter 7: Conclusion and Recommendations. This chapter focuses on the parts of the command estimate that could best be assisted by the use of rule-based expert systems.

Appendix A: Functional Decomposition of the Intelligence Preparation of the Battlefield (IPB). This annex examines the IPB from a systems analysis point of view in the same manner the command estimate was analyzed in Chapter 6. It discusses operational Army requirements combined with an analysis of those portions of the process that can best be performed by an AI-based system and those that are best done with the current manual technology.

Appendix B: Interview and E-Mail Summary. Interviews with subject matter experts conducted via electronic mail, personal sessions and telephone calls are summarized in this section.

Appendix C: Glossary. Technical and domain-specific vocabulary used within this study are defined in this chapter.

CHAPTER 1 END NOTES

[1]U.S. Army, Command and General Staff College, Student Text 100-9, The Command Estimate (1989): 1-2.

[2]Bob Brown, "Future of Network Management Lies in Expert Systems," Network World 37 (September 18, 1989): 11.

[3]ST 100-9 (1989): 1-3.

[4]David W. Rolston, Principles of Artificial Intelligence and Expert Systems Development (1988): 15.

[5]US Army, FM 100-15, CORPS OPERATIONS (APPROVED FINAL DRAFT): 4-10.

[6]U.S. Army, FM 101-5-1, Operational Terms and Symbols (1985): 1-16.

[7]ST 100-9, (1989): 1-2.

[8]FM 101-5, (1984): 5-2.

[9]Paul E. Lehner, Artificial Intelligence and National Defense (1989): 15.

CHAPTER 2

LITERATURE REVIEW

The use of artificial intelligence, and more specifically, rule-based expert systems, in military command and control systems is not a novel idea. The computer hardware and software that could make such a system become reality are available with present technology. However, there are no deployable or successful implementations of rule-based expert systems within any existing or near-term command and control systems.

The command estimate is the essence of military command and control. Determining if rule-based expert systems can be successfully used within the command estimate will set the stage for the future development of military command and control systems.

The purpose of this chapter is to describe the current state of militarily significant rule-based expert systems, define the requirements for battlefield information management, introduce the command estimate, compare civilian executive information systems with

military requirements, and examine some areas of the command estimate and staff operations that have been identified for possible enhancement.

RULE-BASED EXPERT SYSTEMS

The military application of computer systems that aid in decision making is not a new development. Many conventional systems such as TACFIRE and TACCS have proved effective for solving mathematical, statistical, or routine data processing problems. However, the challenges associated with assisting the commander in the process of command and control in combat do not fit into these categories. The solution to such problems are still critically dependent on skill in identifying and relating trends, weighing evidence, developing courses of action, evaluating alternatives, predicting outcomes, and making complex decisions. This can be summed up as the human ability to bring a wealth of diverse knowledge and years of experience to bear on the problem at hand. A computer system to perform in such a manner is called an expert system.[1]

Expert systems are computer programs that duplicate, to some degree, the kind of results achieved by human experts. These systems are able to solve some types of problems, to predict situation outcomes, and to give advice within narrow areas of consideration. One theory defines expertise, or the skill shown by experts,

as the result of the accumulation of a set of rules for interpreting facts to reach a conclusion. The general idea of rule-based expert systems is that if these rules could be collected and put into a computer, then some of the skill of the expert could be shown by that computer.[2]

A detailed examination of specialized aspects of artificial intelligence and rule-based systems can be found in Encyclopedia of Computer Science and Engineering.[3] This work is a tremendous vehicle for general background information but lacks a scope into military applications. Several other books provide a point of departure for the understanding of rule-based systems applicable to the direction of this thesis. They include Fundamentals of Human-Computer Interaction[4] which details expert system structure and knowledge engineering, Winston's Artificial Intelligence,[5] and Principles of Artificial Intelligence and Expert Systems Development.[6] These works excel at the explanation of problem solving concepts and knowledge engineering. However, none of these books provides insight into how rule-based expert systems can assist in military command and control.

A general source of information for rule-based expert systems within the narrow band of military command and control applications is Lehner's Artificial Intelligence and National Defense.[7] It provides a concise source for the explanation of AI as a science and

a crosswalk of several current efforts within the Department of Defense. While it contains an overview of rule-based expert systems in several command and control initiatives, it does not examine their role in the command estimate.

It would be prudent to question why there are no major expert systems currently augmenting military command and control systems. The answer is not simple.

Although expert systems have been around since the 1950s, it has only been recently that they could be operated without reliance on large mainframe computers. Due to this mainframe dependency, they have been restricted to a very narrow scope in application. Additionally, they have required constant programmer maintenance to build and maintain knowledge bases.[8] The interval since 1984 has seen a tremendous downsizing of the expert systems to more transportable hardware, an exponential growth in software capabilities, and an emergence of applications in the civilian sector that promote adaptability towards military uses.[9]

While rule-based expert systems show significant promise in military applications, there are several considerations that limit the scope of their use:

1. There are finite limits to what these systems can currently do. The optimum size for a rule base is between ten and 10,000 rules.[10]

2. They tend to be idiot savants, capable of doing some limited things rather well while not being capable of operations near the fringes of their knowledge bases.[11]

3. Basic rule-based systems do not learn. While the capability of some systems to learn has been demonstrated, this process is not yet at a level of sophistication that would justify a military application.[12]

4. They do not know how and when to break their own rules.[13]

5. They lack the ability of visual or pattern recognition to a militarily significant level. Visual recognition is a primary method used by military commanders and staffs to distill information.[14]

6. Rule maintenance is expensive and time consuming.[15]

7. These systems contain no common sense and can give absurd results.[16] There is no reality checking mechanism other than human interpretation of the results.

8. Human knowledge is often deficient in some areas for even the best or most successful experts.[17]

9. Special and perishable skills rapidly deteriorate as the reliance on and use of the expert system increases. This results in the organization becoming critically dependent on machines.[18]

Once the limitations are understood, the advantages of expert systems can be exploited. Areas in which they can excel and have practicality in military applications include:

1. They can allow soldiers of varying skill levels to approximate an expert in performing a task within the problem domain of the system.[19]

2. They are not subject to fatigue, stress, fear, exhaustion, or emotions. Hence, they can reduce personnel requirements for continuous operations.[20]

3. An important role an expert system can perform is that of a consultant.[21] It could not have a hidden agenda and, therefore, could be relied on for providing information and detail solely based on logic.

4. An expert system can be an advanced checklist mechanism to query the human commander to make sure doctrinal tenets are satisfied.

5. Over a period of time, an expert system can accumulate input from a variety of experts, thus refining its internal expertise and providing system users with an increase in capability.[22]

6. As experience is gained through use of a system, it can provide a corporate memory and historical summaries of past performance on which to measure current operations.

7. Due to the portability of automation equipment, a rule-based expert system can serve as a

transportable equivalent to the Center for Army Lessons Learned (CALL). This would facilitate the dissemination and standardization of newly developed doctrine.

8. In a distributed network, rule-based expert systems can dramatically expand integration of information from a wide variety of sources.[23]

THE COMMAND ESTIMATE

FM 101-5 explains how army staffs are organized and operate to execute the military decision making process.[24] Army staff organizations and functions are based on methods which have evolved over the last century. The process taught to commanders and staffs in arriving at military decisions is termed the command estimate. The methodology for this process is formalized and explained in ST 100-9.[25] The command estimate is a proven manual process. It is a logical and orderly examination of all factors affecting the accomplishment of the mission in order to reach a sound decision. In reality, the command estimate is a continuing mental process for the commander or staff officer who must observe, evaluate, revise, decide, and observe again throughout the duration of a tactical operation. The command estimate is as thorough or as brief as time and circumstances permit.[26]

The command estimate is not a simple mechanical process. Although it is depicted as a flow chart in ST 100-9 (Figure 1, page 4), there are no distinct starting

or stopping points. The components of it are not independent. Many of the elements can occur or be in progress at the same time.[27]

The command estimate is a continuous process. Unless the current mission is changed, or until a new mission is received, commanders and staff officers continuously update and refine information in their respective areas of responsibility. A change in the current mission, the receipt of a new mission, or a change of information provides new direction to this process for that particular operation.[28]

Formal scientific analysis of the command estimate has been conducted by the Fort Leavenworth field office of the Army Research Institute (ARI). The following are ARI's areas of issue and concern in the execution of the command estimate:[29]

1. Time constraints. There is not enough available time to do the prescribed procedures of the command estimate. Consequently, some of the steps are omitted, conducted out of sequence, or performed incorrectly.

2. Cognitive biases. Human adopted strategies can be suboptimal due to the effects of group thinking and consensus confirmation.

3. Information use. The commander and staff fail to actively seek or disseminate information. This

is attributed to the threat of overload for incoming information and the responsibilities associated with the ownership of outgoing information.

4. Information uncertainty. Inherent in any tactical situation is the large degree of uncertainty in information.

5. Overconfidence of the commander and staff. This leads to a misleading implementation of plans and results in the lack of development of contingencies.

6. Lack of experience. With many commanders and staffs, the possibility of an inadequate experiential base to make sound tactical judgments exists.

7. Management of the process. The overall group decision-making process is poor. A fairly common occurrence is that issues are resolved using the last option discussed.

8. Definition of insufficient options. When multiple options are created, they are often simple variations of a main theme. When there is variance, it is normally the practice to generate something to "throw away" to give the appearance that more than one option was considered.

9. Limited scope of the command estimate. The command estimate is often used for other kinds of operations that don't lend themselves to resolution via the military decision model.

10. Decision analysis. The applicability of the command estimate and its components are highly situational dependent.

11. Inappropriateness of the decision making model. The continuous and cyclic nature of the command estimate is not always the optimum method to simultaneously generate and evaluate courses of action.

This thesis will conduct an indepth analysis of the command estimate and examine the adaptation of rule-based expert systems as a means to assist commanders and staffs in its execution.

BATTLEFIELD INFORMATION MANAGEMENT

The commander and staff have unique and specific information requirements for battlefield command and control. Although information is not fully recognized as a combat multiplier, if processed correctly and timely, it can contribute to combat power. A method for managing this information is to divide it into three major functional areas of planning, directing, and executing.[30]

These three areas have seven tasks that the command and control system must do:

PLAN

1. See both friendly and enemy situations.
2. Evaluate the mission.
3. Develop the plan.

DIRECT

4. Allocate resources.

5. Coordinate the allocation, assignment, and reallocation of resources.

EXECUTE

6. Fight the battle.

7. Sustain the forces.

Although manual methods are used in performing these tasks, they are rapidly losing their status as the primary means of managing information.[31] Computers are more accurate and faster than manual processes. Automated command and control information systems have been used to assist in planning, directing, and executing military operations in various forms since the 1960s. Their utility and need are widely recognized as being essential for military operations. There are three primary conditions that justify the expense and effort for implementing automated command and control systems to regulate information handling:[32]

1. The commander's performance ability is saturated under normal conditions because of information overflow.

2. The commander's performance is limited under prolonged periods of stress conditions.

3. Higher accuracies and better reliability of data are needed to make better informed decisions.

The positive effect of introducing a command and control information system is that it can prevent or reduce the burden imposed on commanders, freeing them from routine tasks and allowing them to concentrate on important information and making timely decisions. The problem is that while automated systems do a credible job of getting information to commanders and their staffs, they do little to help sort, sift, filter, merge, collate, or rank the information to assist the commander to make informed decisions. While the raw speed and power of automation is intoxicating, commanders can readily become so immersed in details that they do not have sufficient time to devote to the prosecution of the battle. To fight and win in three separate and distinct battles (close, deep, and rear), information must be properly organized so that the commander is neither flooded with detail or suffers from a lack of critical information.

Too little information makes the command estimate completely ineffective. Too much information slows the process down. Automated rule-based expert systems can be used to intelligently process data and, therefore, optimize the available time within the command estimate.

EXECUTIVE INFORMATION SYSTEMS:
CIVILIAN INFORMATION MANAGEMENT SUCCESS

The civilian sector has turned to a class of computer products called executive information systems (EIS) to manage and leverage information in an attempt to increase profits. Simply stated, an EIS is a computer-based means by which information can be accessed, created, packaged, and delivered for use on demand by high-level, nontechnical executives. An EIS is a hands-on tool that focuses, filters, and organizes an executive's information, so that he or she can make more effective use of it. By using information more effectively and more strategically, a corporation can ultimately increase profits.[33] EIS applications are designed for the non-computer-oriented executives who have neither the time nor the inclination to be trained in computer methods. This definition dovetails with battlefield information management needs of commanders and staffs.

The goals of an EIS are also in line with those needed in a commander's battlefield information system.[34] In the following list of goals for an EIS, the words "commander and staff" can be interchanged for "executive" or "management team."

1. To reduce the amount of data bombarding the executive.

2. To increase the relevance, timeliness, and usability of the information that does reach the executive.

3. To focus a management team on critical success factors.

4. To facilitate information comprehension and communication with others.

5. To enhance executive follow-through.

To meet these goals, a commercial EIS product Commander has the following modules:

1. Status reporting via an electronic "briefing book." By using this application, each executive can receive a focused selection of reports and charts, which reduces the amount of irrelevant information. Specific tolerances can be designated that result in rapid exception reporting. The information feeding these status reports is constantly updated.[35]

2. E-Mail management. In this module, information can be rapidly disseminated to specific agencies or individuals within the organization.[36]

3. Free-form data base queries. This feature allows the executive to seek detailed information if required. Multiple levels of investigation are possible that cannot be done using paper reports. Dynamic relationships between data elements can be designated and investigated through corporate data bases. It also gives the ability to play "what ifs" with current data sets.[37]

4. Reminder capabilities for tracking and follow-through. This is an electronic suspense and calendar system that can assist in complex synchronization of scheduled events. Project management is also a facet of this feature. Critical dates and events can be managed with this system.[38]

5. Delivery of current news of the world outside. Information that is critical to the decision maker can be accessed as it comes "on line" via news or stock market reporting services.[39]

The spread of EIS is growing within civilian industry. IBM has introduced a line of products which target corporate chief executive officers, managers, and planners.[40] Another initiative in the civilian sector is the reduction in the number of middle level managers by using EIS to give the executive more control of information.[41]

EIS is being incorporated into civilian information management infrastructures because managers can obtain information faster, make better decisions, and communicate more effectively. The commonality of military and corporate information management requirements are obvious. The power and abilities of corporate EIS have not been overlooked in regard to military applications. The use of an EIS has a logical place in the evolution of an automated command and control system. These systems would allow the commander

to monitor the four or five items of critical information that he routinely needs to make qualified and informed decisions.[42] Advantages of the EIS architecture are that it lets the commander get the information "off line" without redirecting the efforts of the staff and that it avoids the tendency of commanders and staffs becoming bogged down in data overload.

The five internal modules of the commercial product Commander have direct application to the command estimate process:

1. Status reporting. The command and staff elements have to have truth in the status of personnel, equipment, and logistics.

2. E-mail. Electronic mail is a superior method of transferring large volumes of data as compared to hard copy message and voice radio.

3. Free-form database queries. This gives freedom to access large amounts of data, allows a higher echelon commander or staff to acquire information for future planning without distracting lower echelons from current operations.

4. Reminder Capabilities. This application provides assistance in tracking time-critical events which would benefit planning and directing within the staff estimate. Complex projects could be managed using this module.

5. Delivery of outside news. This feature contributes to the commanders insatiable need for current information.

Artificial intelligence and rule-based expert systems are now being incorporated into civilian EIS.[43] This trend has direct translations to military applications. A rule-based expert system incorporating the goals and applications outlined for an EIS can serve as the architecture for an intelligent automated command estimate.

PERFORMANCE ENHANCEMENTS

There are several areas of the command estimate and staff actions that have been identified as high return functions for enhanced performance. A study performed by Army Research Institute suggested the following areas could be analyzed better by using an automated system:[44]

1. Tactical Courses of Action.
2. Battlefield Area.
3. Tactical Capabilities.
4. Enemy Threat.
5. Logistical Capabilities.
6. Tactical Courses of Action.

Of these areas, evaluation of the enemy threat is the area that the use of rule-based artificial intelligence will have the greatest impact.[45] Such a

system could significantly increase the capabilities of the commander to better understand the threat and anticipate enemy battlefield action. The result is that better informed friendly courses of action could be developed.

Another area of that could benefit significantly from enhancement with rule-based systems is the analysis of tactical capabilities. This could be done for both friendly and enemy forces. The ability of such a system completely outstrips the coarse method of comparison currently used in the present manual process.

A third area that could derive significant enhancement through assistance by rule-based expert systems is the analysis of logistical capabilities. The current manual procedures for using staff planning factors are prone to calculation errors and misinterpretations by human operators. A rule-based system could do such calculations with a greater precision and with much more empirical detail.

RULE-BASED EXPERT SYSTEM WAR GAMING

War fighting applications in the form of mathematical models and simulations, are a relatively recent addition to military planning and decision making.[48] Automation is essential to the use of these models and simulations due to the large amount of computations required to perform them. One of the

strengths of using automation to do this is that it can allow for numerous "what-if" analyses of a problem being modeled. This gaming process provides the rapid testing of the validity of ideas and plans.[47] The ability to test plans and operations has immediate military utility.

The current method of performing the validity test of military plans is a manual war gaming process. This logical step-by-step process relies heavily on tactical judgment and experiences. It focuses the attention of the staff on each phase of the operation in a logical sequence. The process is one of action-reaction-counteraction.[48] However, the manual analysis process is time-consuming because of the number of combat, combat support, and combat service support units involved in military operations. War gaming is an evaluation process in which planners mentally play through tactical movements and combat engagements. This methodology is a highly interactive process where players visualize the flow of battle and attempt to determine advantages and disadvantages of a planned operation. One benefit of automating this process is the elimination of manual bookkeeping chores required to track the position, strength, and missions of the numerous units.[49]

The availability of advanced technologies, such as artificial intelligence (AI) and improved communications, is driving military training systems to new levels of sophistication. Since AI allows

simulations to function in the same way as an enemy would in battle, it will provide key capabilities for training against the Soviet threat.[50] The obvious adaptation of rule-based expert systems to such an environment would provide a dramatic increase in the capabilities of commanders and staffs to know the threat, to better anticipate his actions, and thus to develop better battle plans.[51]

While rule-based expert systems would assist in the war gaming process, it should be recognized that the use of the advanced technologies cannot improve upon human judgement, they can provide analytical tools for analysis, filtering of information, and performing computations. These tools support decision making.[52]

CONCLUSION

The command estimate can be improved with advanced technology which can be patterned after demonstrated successes within civilian industry. The use of rule-based expert systems can be the vehicle for the future improvement and development of military command and control systems.

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CHAPTER 3

RESEARCH METHODOLOGY

This study used research of available literature, interviews of subject matter experts, and systems engineering techniques to examine the command estimate process in detail.

INFORMATION SOURCES

The primary means of gathering information was the literature search. The Combined Arms Research Library (CARL) provided the initial information and a conduit to the Defense Technical Information Center (DTIC). However, CARL was soon exhausted as a primary source and alternates had to be obtained. Several CGSC students had references in their personal libraries that provided much of the current literature used in this study. Additionally, the use of periodicals, magazines, and computer industry literature proved a rich infusion of information.

RESEARCH TOOLS

Since the essence of this thesis is the use of advanced computer techniques in military command and

control, automation assets were used to the fullest extent. A tremendous tool used to organize the gathered information was the software MemoryMate, a hypertext data base system.[1] It was used to manipulate the research material to indicate linkages between separate documents and references with designated similarities. Dynamic search criteria were designated to produce combinations of relationships which allowed for rapid and frequent organization of the material. For example, a search was conducted through the data base containing more than 100 documents for the occurrence of the phrase, "automated command and control" within each document. Within seconds, the search was completed indicating the number of documents containing the phrase. In turn, each document was listed which enabled the investigator to review pertinent material.

Additionally, "hyperlinks" were established between specific passages in a particular document and "buttoned" to other words or phrases in other documents. An example of this use of MemoryMate was a document containing the phrase "expert system" which was hyperlinked to another piece of literature containing a detailed technical definition of that phrase. When a search was executed which brought up the first document, the hyperlink button indicating the technical word could then be toggled bringing up the linked document and displaying the technical definition. Specific words or

phrases in this second document would in turn be buttoned to still other documents. This allowed rapid collating of ideas or thoughts and linked them much in the way people think instead of the traditional linear way computers or word processors function.

Before this method of literature research could be performed, the documents had to be input into the computer. This was normally accomplished by manually entering the documents into MemoryMate. Another method for transferring material was by way of electronic mail (E-Mail). E-Mail input of documents was most preferred. Manual input of the documents into the computer did not prove cost effective unless the documents were short.

Once the hypertext process was complete in a literature research, a complete document, or relevant parts, could then be electronically transcribed to the thesis.

Electronic Mail (E-Mail) was used to the maximum extent to communicate with subject matter experts and to transmit and receive applicable information. The primary vehicle was the Defense Data Network (DDN). The E-Mail interviews were conducted in the same manner as a conventional interview with the exception that they did not occur in real time. This method had the advantage that questions could be well thought out and answers could be explored in detail.

SELECTION OF SUBJECT MATTER EXPERTS

Subject matter experts were often nominated by interview subjects and from several listings provided by members of the research committee. The basic parameters that form the qualification of an expert varied to the subject matter. Experts for the structure and methodology of the command estimate were found within the Center for Army Tactics (CTAC) at Fort Leavenworth. This group is the Army's focal point for tactics doctrine and instruction.[3] The command estimate process is taught to students of the Command and General Staff College in several courses to include Combat Operations, Operational Warfighting, and Applied Tactics.

Experts for command and control in general were found at the Combined Arms Training Activity Center for Army Lessons Learned (CATA-CALL) and the Army Research Institute (ARI) Field Unit. Both agencies collect data and assess the performance of command and control for the Department of the Army.

Authorities in artificial intelligence and rule-based expert systems with respect to military applications were difficult to find. The components that establish an expert include both education and experience in military applications of rule based systems. The US Army Artificial Intelligence Lab, West Point, New York was the primary source for expertise of rule-based systems in military applications.

SYSTEMS ANALYSIS OF THE COMMAND ESTIMATE

The focus of this thesis is the analysis of how rule-based expert systems can assist in performing the command estimate. To conduct this analysis, the command estimate was examined using techniques of systems analysis. A structured decomposition of the separate functions within the process has been created using systems analysis techniques as taught by the United States Army Systems Automation Course. This course is the source of training for Army Systems Automation Officers who carry a functional area identifier of 53.[3] The end analysis of this effort illustrates which sections of the command estimate are best performed by a manual process or by assistance from a rule-based expert system.

The first method used to look at the command estimate is that of data flow diagrams. This use of traditional methods of systems analysis of the basic components of the command estimate is done from a soldier/staff officer perspective. The process traces the flow of information into the command estimate, how it is processed, and where the information goes once it is used. Data flow diagrams are the conventions used to perform the structured decomposition of the command estimate. This method is drawn from structured software engineering techniques normally used in the process of automating functions within business environments.[4]

The intent of this process is to use symbols and text to describe the sequence of functional operation and information flows within the command estimate. The symbology differs from the formal structure as depicted in ST 100-9.

A graphic analysis model of the command estimate was created to increase the understanding of the process. The basic component of the structured analysis model was the data flow diagram (DFD).[5]

Each discrete process of the command estimate was modeled using DFDs composed of four basic components as depicted in figure 2. These components are:

1. A source or sink is the system interface with the external world. This is where information either enters or leaves the system.[6]

2. A process is where transformations of the information occurs.[7]

3. Data flows represent the flow of information from one part of the system to another.[8]

4. Data stores are where information is kept or deposited. This is often a temporary store of information as it awaits processing by another part of the system.[9]

A simplified example of data flow using this terminology would be a rule-based expert system designed to maintain the status of artillery units in a division using input from different status reports. Unit statuses are received in message form. This input of information

DATA FLOW DIAGRAM

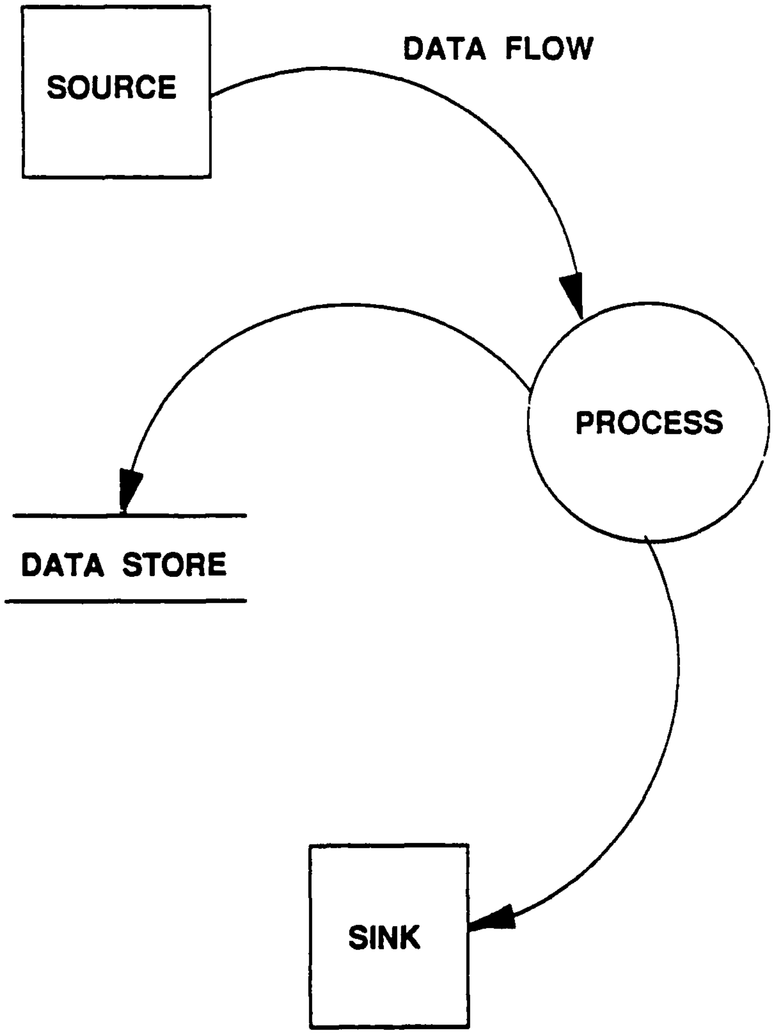

FIGURE 2.

is the source. The statuses of personnel, equipment, and supplies form the data flow that goes into the process of maintaining artillery unit status. In the process, the rule-based system filters-out the following information that is unique to artillery units: unit designation, artillery equipment, artillery supplies, and artillery personnel. The process then sends this information to a data store where the information updates any previously existing data. A report is then generated reflecting the current status of artillery units. This report will be used by commanders and staffs for planning and decisions. This report is an information sink, or the point at which the information goes external to the rule-based system.

A second methodology used to examine the command estimate was identification of areas that have been documented as poorly executed and the use of personal observation by functional area experts.

Documented sources included the Army Lessons Learned Management Information System (ALLMIS) provided by the Combined Arms Training Activity Center for Army Lessons Learned (CATA-CALL).[10] The Army Research Institute (ARI) also provided sources.

Several tactics instructors in the Command and General Staff College Center for Tactics (CGSC CTAC) provided input based on observations of what is successfully done and what is routinely not done well in

the performance of the command estimate. I then examined these areas with respect to the feasibility of using rule-based expert systems as staff-aids in enhancing the execution of the command estimate.

CHAPTER 3 END NOTES

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CHAPTER 4

IS THERE A NEED FOR RULE-BASED EXPERT SYSTEMS IN COMMAND AND CONTROL?

US Army Field Manual 100-5 sets three criteria for a superlative command and control system.[1] First, it must optimize available time. Second, it must stress sound doctrine in operations and staff practices. And, third, it must allow the managers of the battlefield operating systems to position themselves where their presence has the greatest impact. Manual methods of performing command and control are no longer viable. Current and emerging automated command and control systems were not designed to operate in the environment envisioned for AirLand Battle. The future for automated command and control systems lies in the use of rule-based expert systems.

The purpose of this chapter is to analyze and examine the following topics:

1. Why current automated command and control systems do not perform battlefield information management.

2. The need to counter the Soviet approach to automated command and control.

3. Intelligent information management on the future battlefield.

4. How ATCCS will overload commanders with information.

The conclusion will demonstrate how rule-based expert systems, assisting in the command estimate process, can satisfy the three criteria for an outstanding command and control system.

WHY CURRENT AUTOMATED C2 SYSTEMS DO NOT PERFORM BATTLEFIELD INFORMATION MANAGEMENT

The Maneuver Control System (MCS) is the automated workhorse that is being fielded in an effort to take advantage of computer technology. However, MCS was not designed for AirLand Battle doctrine and does not satisfy the commander's battlefield information management requirements.[2]

MCS provides a narrow range of support functions. In addition to normal office automation such as word processing, spreadsheets, E-mail, and data base management, the system provides a sophisticated tactical communications interface, map overlays, graphics, and limited automatic staff reporting. As limited as MCS is,

no other system of similar magnitude and capabilities exists that links tactical and operational levels in the Army.[3]

When evaluated during use in an advanced tactics course taught at the United States Army Command and General Staff College in 1989, MCS received a "Leavenworth C" which means that it marginally met standards.[4] The good points were that the system was excellent for passing short messages, had an acceptable database management system, provided units the needed capability of duplicating written information at more than one location, and provided staff officers MS DOS capabilities in the field. However, the system did not significantly improve the commander's maneuver control capability or the management of information.[5]

In reality, MCS's contribution to the command and control process was E-Mail and limited database management. While the E-mail and database capabilities were definitely valuable assets, by themselves they did not significantly help the commander see the battle and make decisions.

In its current form, MCS does not provide a justifiable return on the investment in effort required to train the users and feed information into the system. An automated system should not require more manpower and time to do the job than the manual method it replaces. This is not the case with many MCS features.[6]

For any automated command and control system to be helpful, it must do three things:

1. Provide a top-down high speed review of aggregate information where the effect of anomalies or problems can be tracked.

2. Show trend analysis.

3. Provide exception reporting with an ability to isolate problems where they occur.

In the final analysis, MCS provides data, not information. What is needed is a system that is intelligent enough to assist the commander in rapidly filtering the available data. Rule-based expert systems can provide the commander with the automated assistance needed on the modern battlefield.

AUTOMATION IN SOVIET TROOP CONTROL

Soviets consider automation a key element in the technical aspect of command and control. They recognize that it is a superior method of assisting in the development of detailed plans.[7]

Current Soviet efforts to improve troop control appear to be aimed at expanding availability of modern control equipment, especially automation.[8] Due to technology transfer, US qualitative hardware advantages are eroding. Therefore, it is important to capitalize on the ability to better manage and exploit information.

The use of rule-based expert systems in critical areas such as the command estimate is the best way to accomplish this.

BATTLEFIELD 2000 +

Technology has insured that future armed conflicts will be more intense, violent, and chaotic than experienced in the past. Near-real-time information and intelligence will become more critical than ammunition, fuel, and spare parts. The commander will be forced to wage a 'data war'.[9] Far flung sophisticated sensor systems will flood intelligence data bases with the input of vast amounts of raw information. Across the board, the battlefield operating systems (BOS) will have voracious appetites for high volumes of current information.

Widely dispersed operations of US forces will require commanders to monitor a large battlefield. High tempo operations for sustained periods will put stress on battlefield operating systems' survivability and endurance. Enemy capabilities will approach parity with our own. This environment will give the commander even less time to monitor, decide, and act than he has today.[10]

A conclusion that can be drawn from this picture of tomorrow's battlefield is that the complexity of modern technology is giving rise to an increasing number

of situations where any one human commander is incapable of processing the volume of information involved in making reliable and informed decisions. The key to success in this environment is superior command and control through intelligent information management.

The command estimate is the engine to decision making behind the Army's process of command and control. On tomorrow's battlefield, it will need to be augmented with automation to shorten the decision cycle. The use of rule-based expert systems will allow the intelligent filtering of data to produce useful, meaningful, and timely information for the commander and staff.

ATCCS: AN INFORMATION FIREHOSE

The Army Tactical Command and Control System will provide an integrated family of interoperable systems, or "system of systems" to support commanders in command and control (C2) of their forces. ATCCS will be employed in all theaters, at echelons corps and below to support battlefield information functions. ATCCS will support the distribution of information, data and digital graphics among the Battlefield Operating Systems.[11]

As a system of systems, the thrust of ATCCS is to provide the organization, facilities, and procedures through which the commander plans, directs, controls, and

coordinates operations. The commander frames his command and control structures with a physical arrangement of staff and facilities.[12]

ATCCS is not an end to itself, but is the conduit through which the commander will exercise command and control on the battlefield. As a continually evolving and integrated system, ATCCS presents the dilemma of a two-edged sword. The immediate benefit is the incredible panorama of detailed information the commander can harvest on virtually any aspect of the battlefield. The detriment is the same commander being overwhelmed by more information than can humanly be assimilated and used in making good and timely battlefield decisions.

The concept of ATCCS is needed to get control of the command and control architecture. However, ATCCS is primarily concerned with the fielding of standard hardware and software suites to provide commonality across the battlefield operating systems (BOS). The theory is that it would then be possible to effortlessly pass information from BOS to BOS. The evolutionary approach and the rigid adherence to standard protocols, standard message text formats and standard data elements insures that the commander will be force-fed a continuous flow of information. Unfortunately, the software, as currently envisioned, is not revolutionary enough to provide the commander with more than masses of raw data.[13]

There is a pressing need for something to be done to assist the commander in processing this information. The use of rule-based expert systems is a promising alternative in assisting the commander in choosing an intelligent course of action based on the overwhelming amounts of available information.[14]

THE EXPERT SYSTEM TOOL BOX

W. A. Teeter stated that expert systems could serve three distinct roles in aiding the commander's decision process.[15]

1. Consultative Expert systems.

2. Interactive advisor.

3. Thoroughly integrate all elements of the command and control system.

The consultative expert system would contain the rules and methods of battlefield operating system functional area experts. The commander and staff would have access to an honest broker for adherence to US Army tactical doctrine. It would ensure that the commander addresses all the battlefield operating systems in plans and orders. It would be the "what if" agent and provide the commander and staff with a means of examining one or more permutations of a defined course of action.

The function of interactive advisor would allow the system to run in a background mode where it would only surface when a diversion from established tactical

rules is sensed. It would alert the commander's attention to the infraction and make recommendations formulated on knowledge-base rules or heuristics. Also, this system would be on call to answer questions or make mathematical calculations.

The system would integrate all staff components into the command estimate process via the communications facilities of ATCCS. This would allow the commander and staff members to physically be at diverse locations on the battlefield while simultaneously maintaining active participation in the command estimate process. The staff would no longer be in conflict over the need to congregate at a headquarters location if their presence is required elsewhere.

SUMMARY

The time available for planning is the single most important determinant of the number and types of planning tasks that can be performed in the command estimate. In combat situations, the planner may be forced to shorten or curtail many of the planning tasks normally performed given sufficient time.[18] A rule-based expert system could greatly assist in this effort by assisting in the optimization of available time.

Due to the complexity and integration of the battlefield operating systems, it is becoming

increasingly necessary to apply correct doctrine to combat situations. The commander and staff need automated assistance to coordinate battlefield operating systems while applying correct doctrine during planning. Rule-based expert systems acting as the cooperative consultant could ensure that all doctrinal tenets are considered and addressed.

The management of time and the doctrinally correct integration of battlefield systems is made more complicated by the large geographical area involved. By its nature, a rule-based expert system integrated throughout ATCCS would allow the commander and staff to be at critical locations and still fully participate in the command estimate process.

The technology is here and has been successfully demonstrated within demanding civilian applications. The use of rule-based expert systems within the command estimate is key to success on tomorrow's battlefield.

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[8]W. Robert Reeves, "Soviet C3: Theory and Practice," in Jon L. Boyes and Stephen J. Andriole, eds. Principals of Command and Control (1987): 285.

[9]Eberhardt Rechtin, "Command and control in the years 2000 + ," PG 468: from Principles of C2.

[10]The Joint Chiefs of Staff, 1989 Joint Military Net Assessment, CM-1943-89 (May 1989): 7-8.

[11]US Army, "Functional Description of ATCCS," The E-Book (TC 11-7): (1988).

[12]US ARMY, Army Command and Control Master Plan, Volume I, Concepts and Management (1989): 2-7.

[13]US Army, "Functional Description of ATCCS," The E-Book (TC 11-7): (1988).

[14]Joseph S. Yavorsky, "Development of a Prototype Multichannel Communications Network Maintenance Expert System," MMAS Thesis, USA CGSC (1987): 10.

[15]Teter, "Expert systems: Tools in the Commander's Decision Making Process", (1986): 29.

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CHAPTER 5

OBSERVATIONS OF THE COMMAND ESTIMATE

The command estimate is a reliable and proven process that will not be changed in the near future. Given trained, well rested, and experienced commanders and staffs with adequate time, it will consistently produce superior results.[1]

Given the premise that the command estimate will continue to be the primary vehicle for commanders and staffs to perform mission planning, it can be examined and analyzed to determine if there are any areas that can be improved with assistance from rule-based expert systems. The focus of this chapter is to analyze formal observations made by the Center for Army Lessons Learned (CALL) and the Army Research Institute for the Behavorial and Social Sciences (ARI), as well as informal observations of subject matter experts in the area of the command estimate.

THE SUCCESSFUL COMMAND ESTIMATE

An observation was made that the commanders and staffs that perform the command estimate well demonstrate three common things:[2]

1. The commander's intent is thoroughly understood by the staff and subordinates.

2. The staff and subordinates know and understand the commander's information requirements. It is from these items of information that the commander makes his tactical decisions. Focusing on these items puts everyone on the "same sheet of music."

3. The actions of the staff are orchestrated. This orchestration is normally performed by someone other than the commander. Predominantly the G3/S3 operations officer is the staff orchestrator. Techniques vary, but the common denominator is that the staff officers are kept focused and share information.

Unfortunately, few organizations perform the command estimate well. Many of the problems are a simple reverse of those things done by successful units:

1. The commander's intent is not understood.

2. The wrong information is given to the commander.

3. There is no time management and orchestration of the staff.

An additional area is a failure to integrate battlefield operating systems (BOS) into mission planning.

FACTS AND ASSUMPTIONS

An area of the command estimate process that suffers problems is the use of quantitative procedures routinely performed by the S3 and S4 officers. Simple calculations to generate march tables, forecasting logistics, and other mathematical based projections are measurably degraded as time is compressed and staff officers are denied sleep.[3]

The computational skills of automation have long been recognized. A system is needed that would assist and automate use of planning factors. A rule-based system could interact with staff planners and assist in maintaining the current status of equipment and supplies by constantly performing quantitative and trend analysis.

MISSION ANALYSIS

The analysis of time is a critical aspect of battlefield synchronization. Unfortunately, commanders and staffs do not analyze and manage time well. Even among well trained staffs, crisis management often determines the amount of time and detail being devoted to

a task. As a consequence, the most trivial aspect of an operation often receives more attention than is necessary with the result of more important items being dealt with in cursory fashion or completely ignored. Additionally, staffs often mismanage the time for planning at their own level and deny subordinates adequate time to plan and prepare for the operation. The traditional rule of thumb for taking 1/3 of the available time for planning and giving subordinates 2/3 of the time is often abused.[4]

The command estimate is time dependent. Whether or not it is performed, and the quality to which it is performed, is based on the time available between receipt of the mission and time of execution. There needs to be improvement in the analysis of available time and how to best use it. Additionally, there is no one to act as the time manager to ensure that staff actions and planning are done in a timely manner to meet mission objectives.[5]

A rule-based expert system could establish a time table to accomplish staff planning and allow adequate time for execution. The key here is a tool, that when given the time frame from mission receipt to mission execution, can time-manage critical tasks. This tool must be able to determine how long each sub-process of the command estimate should take, based on historical analysis of that unit's performance, and suggest those steps that can be

abbreviated, combined within other steps, modified, or completely ignored. Units must get at least the 2/3 time available to adequately prepare and rehearse.

The commander and staffs on today's battlefield do not lack a sufficient amount of information. They are given an overwhelming amount of raw data. What is needed is a good and timely analysis of this information. The actual analysis of this information is cognitive intensive. It is slow. Good analysis normally comes too late to be of significant use to the commander in the formulation of decisions. Also, the quality of information coming from higher and lateral echelons is often poor. What the commander needs is rapid and correct analysis of information that is needed to make battlefield decisions.[6]

Typically, the commander bases the majority of his tactical decisions on only five or six major categories of information. These are normally established through experience and the commander's "feel" for the situation.[7] Once the information requirements of the commander are defined, a rule-based system can rapidly filter and collate the volumes of information to present trend analysis or exception reporting. This would provide the commander with information focused along a predefined

critical path. It would also indicate those items of information that are missing or do not fit into established parameters.

COMMANDER'S GUIDANCE

The commander's intent is the most critical element of any military operation. It is the desired end-state of what the forces are to achieve. A significant problem in the information flow through the staff is that the commander's intent is usually not specific enough. Nor is it always disseminated to the appropriate staff agencies. This causes confusion and is counterproductive because it allows effort to be expended on what the staff perceives to be the desired goals of the commander. There is no standard method to convey the commander's intent. It is normally given either orally, graphically, or in a written paragraph. A combination of a sketch supported by a written narrative is the most effective method to impart this information to subordinates. This is normally achieved on a single piece of paper or view-graph overhead.•

A rule-based system could play the trusted consultant in the expression of the commander's intent. It could assist the commander in the construction of understandable word pictures. By performing a correlation between the narrative and sketch, it could insure that the

graphics and verbiage are mutually supporting and meet doctrinal standards as well. It could also insure that it is properly distributed to the staff agencies and subordinates that need it to generate staff estimates and produce information.

Commanders often fail to adequately deliver guidance to staff planners and subordinates. This is normally a simple problem of the commander not articulating well enough to the staff the initial intent of what is to be accomplished. Observations indicate that this step is unorganized or compounded by problems with basic terminology and semantics. Another failure to convey the commander's intent is simple omission in communicating the information to lower echelons.[8]

A rule-based expert system could insure that the commander's guidance, mission, and other vital pieces of information get disseminated to the appropriate staff and planning elements. It could constantly poll the various staff elements to ensure they know and understand the guidance. As a cooperative assistant, such a rule-based expert system could be the commander's honest broker to insure that the intent included doctrinal requirements and addressed all BOSs.

DEVELOP COURSES OF ACTION

In developing possible courses of action, steps are frequently omitted or conducted out of order. This is attributed to lack of training of commanders and staffs. Additionally, some staff members are not always present to give their input so specialized expertise is ignored or interjected at a later point in the process.[10] This activity is based on the process of brainstorming. Imagination and creativity are required out the process follows a logical sequence of analytical steps to keep the courses of action within the realm of feasibility. The omission or incorrect sequencing of these steps can invalidate the course of action that is developed.

An additional problem in staff training is the inability to coordinate with other staff elements or with different echelons. During operation Urgent Fury, a lack of command and control was observed between the division and corps environments.[11]

The old saw that, "Ten percent of the organization never gets the word," could be obviated with a system that is responsible for information dissemination. The system could be the coordinator between staff elements and insure that actions of any one staff section are done in consonance with the other sections. A primary advantage of an automated system is that it could leverage the information interfaces that

exist between the different staff elements.[12] These exist where more than one staff section needs a particular set of information or where a staff section has to receive information from one or more other sections. The expert system could insure that the information is shared among staff elements. The Chief of Staff, or Executive Officer at lower levels, could monitor the information interfaces and would have a tangible point from which to influence overall staff efficiency.

A rule-based expert system could monitor that the steps are done in the correct sequence and provide assistance if not enough information is available to perform a step. Also, a distributed system that uses the ATCCS communications architecture could obviate the need for the entire staff to be physically present in the TOC for planning and performing the process of testing, or war gaming, courses of action.

Staffs are not well trained to synchronize the BOS when developing courses of action. Of the five BOS, only maneuver, command and control, and fire support are routinely included. Air defense and combat service support are often only included when a question arises that prompts their inclusion. Intelligence-electronic warfare and mobility-countermobility-survivability are often completely neglected.[13]

A rule-based expert system could act as a tactics honest broker. It would ensure doctrinally correct integration of all of the BOS during the development of courses of action. It would help in the prioritization of their use. It would verify the planned use of each BOS during war gaming.

A final problem with the state of staff training is the integration of different types of forces or special doctrine. This is particularly evident in course of action development and analysis. In the former, resources are often completely overlooked or not used to the fullest extent of their capabilities. In the latter, they are often completely omitted.[14] Examples are Special Forces and general corps-level assets. Staffs at brigade and division levels generally do not know how to employ these resources.

An expert system could have modules for various force packages that could be employed. An example is for a module containing expert rules for light infantry operations to be used by an armored division commander and staff. Another example might be a module for a corps staff to use in developing plans for using a Marine Amphibious Unit in coastal area operations. After aiding in plan development, a rule-based expert system could also assist in monitoring the use of these assets. More

mundane would be modules dealing with each battlefield operating system to insure that they are being used correctly with respect to doctrine.

Intelligence preparation of the battlefield (IPB) is not incorporated well into the command estimate. If done at all, it is normally performed in isolation and never impacts on the formulation of courses of action until after they have been conceived. The IPB should be continuous. Flexibility is lost because the IPB process normally stops when a particular course of action is decided on.[15]

The continuing process of IPB could be performed as a constant background task of a rule-based expert system. It would be totally integrated into the process of each staff section. It would run continually and divide the battlefield into close, deep, and rear areas. An impressive capability of such a system is the ability to continuously produce doctrinal and situational templates of the enemy. It would also be able to determine if the ground truth, or what is being observed and reported, of enemy activity versus enemy doctrine is not consistent. This could indicate enemy deception and reduce the ability of the enemy to achieve tactical and operational surprise.

ANALYZE COURSES OF ACTION

The single major problem units are observed to have in using the command estimate is synchronization of the BOS.[16] The method as outlined in ST 100-9 is the use of a matrix to identify and list, in sequence, the critical tasks developed during war gaming courses of action.[17] This allows for the synchronization of battlefield activities in time and space. The amount of detail produced in this synchronization matrix is related to the commander's and staff's abilities, time available, and needs.

This synchronization matrix is often not used correctly or not used at all due to time compression and the fact that it is mildly complicated. The difficulty in using this manual tool is attributed to staffs, as seen at NTC, which are often tired and deprived of sleep. The use of such tools requires a high degree of cognitive awareness that most of the staff officers lack after several days of continuous operations.[18]

A rule-based expert system could maintain critical events and assist in developing the synchronization matrix during war gaming. Also, neither friendly or enemy logistical considerations are well orchestrated into the war gaming process. The expert system could track and maintain a current data base of logistical statuses. Such a system would keep the

synchronization matrix dynamic. This syst m would allow for the matrix to be updated as facts replace assumptions or as logistical/operational parameters change. The level of detail could be as significant and focused as necessary. The system would execute a cross checking process to insure that all the applicable BOSs have been incl ed in the synchronization process.

Once courses of action are developed, they are methodically analyzed to determine the best course of action to pursue. The primary vehicle for this analysis is war gaming. This phase is often not done well because the relative level of training within the staff. A primary player is the S2 officer. Unfortunately, at battalion and brigade level, this is often a junior officer with little experience. The underlying theme is that staffs in general do not have the training or experience to conduct adversarial war gaming well.[19]

Ideally, a rule-based expert system could be both an assistant and a tutor. It could train the staffs as they do their mission. Based on a docrinally correct rule-base, it could excel as a threat adversary during the process of war gaming courses of action.

OPORD/FRAGO PRODUCTION

A final observation of breakdowns for the command estimate process is a failure to generate and disseminate

operations plans, operations orders, and fragmentary orders q·ickly enough or in enough detail to be used in a timely manner. Again, this is one task that degenerates as time compresses and as people suffer from fatigue. Another factor that influences the delay in orders dissemination is the inability to get and maintain accurate logistical information. The result of this failure to get orders out invariably led to confusion and operations that were not well synchronized.[20]

An expert system would excel in the production and dissemination of orders. It could perform redundancy ·- ecks such as ensuring accuracy of grid coordinates and time zones, that all applicable units were addressed within the order and as recipients of the order, ensure that the BOS were adequately addressed and coordinated, and that the orders were disseminated to meet time management thresholds. In cases where orders are sent out with incomplete information, the expert system could do the accounting function of making sure that supplementary information was delivered to the units that needed it as it became available.

ABBREVIATED COMMAND ESTIMATE

Time is normally the most precious commodity on the battlefield. In tactical operation it is often the case that there is not enough time to perform a formal

command estimate as outlined in ST 100-9. When this is the case, an abbreviated command estimate must be performed. Although ST 100-9 contains a chapter on an abbreviated command estimate, it does not shorten the number of steps the commander must perform.[21] In the abbreviated command estimate, all the steps need to be done. What is needed is assistance in showing the commander and staff what steps in the process may be shortened. This is currently based on experience or left to chance.[22]

One of the strengths of an automated rule-based expert system is that it can perform the time analysis and continually prompt various staff elements for specific items of information that are time sensitive or critical at particular points in the command estimate process. Another part of the time management function would be management of an abbreviated process of the command estimate. This could be accomplished by using historical data or the most recent statuses of both friendly and enemy forces.

SUMMARY

The command estimate is a superb vehicle for teaching commanders and staffs correct methods for analyzing mission requirements, developing possible courses of action, and comparing alternatives to provide

the optimum means for accomplishing the mission.[23] However, the observations in this chapter indicate that the implementation of the command estimate is often poorly conducted.

Based on observations of the command estimate, the following components of the command estimate are recommended targets for assistance by rule-based expert systems.

1. Facts and assumptions.
2. Mission analysis.
3. Commander's guidance.
4. Develop courses of action.
5. Analyze courses of action.
6. Produce OPORDs and FRAGOs.
7. Conduct an abbreviated command estimate.

Table 1, chapter 5 summary, displays the components of the command estimate and the type of rule-based expert system that can be implemented to assist each process.

The use of rule-based expert systems can contribute significantly to the command estimate. Specifically, they can assist in clearly conveying the commander's intent, insuring the staff provides the commander with the proper information, providing time management and orchestration of staff activities, and synchronizing the BOS consistent with doctrine.

CHAPTER 6 SUMMARY

COMMAND ESTIMATE PROCESS	TYPE OF RULE-BASED SYSTEM
Mission	Normalize Data Maintenance Consultant
Facts and Assumptions	Data Maintenance Computation
Mission Analysis	Synchronize Normalize
Commander's Guidance	Consultant Normalize Production Output
Develop Courses of Action	Synchronize Consultant Production Output
Intelligence Preparation of the Battlefield (IPB)	Perform IPB
Analyze Courses of Action	Synchronize Concuct War Game
OPORD/FRAGO	Normalize Production Output
Abbrieviated Command Estimate	Synchronize Normalize Consultant Production Output

TABLE 1.

CHAPTER 5 END NOTES

[1]Lecture notes of MAJ David Goebels, CTAC Instructor, 10 Jan 90.

[2]Interview, Major John Kelly, CTAC Instructor, 24 Jan 90. (Cited hereafter as Kelly).

[3]Interview, Captain Tony Garcia, Center for Army Lessons Learned (CALL) Command and Control Analyst: 12 January 1990.

[4]Army Lessons Learned Management Information System, Full Observation Report 3305, CALL Index D39022, 88/07/07. (Cited hereafter as ALLMIS).

[5]Kelly, 24 Jan 90.

[6]Ibid.

[7]Interview, LTC Tichenor, CTAC: 22 Jan 90. (Cited hereafter as Tichenor).

[8]Kelly, 24 Jan 90.

[9]ALLMIS 195, CALL Index D00050, 85/1113; 4125, CALL Index 200074, 88/12/29; 3372, CALL Index D40017, 88/04/11.

[10]Ibid 3164, CALL Index D08710 87/10/01

[11]Ibid 20, CALL Index B31026, 85/11/12; 740, CALL Index D00040, 86/01/07; 3522, CALL Index D39042, 88/07/11; and 1759 CALL Index 86/04/07.

[12]Ibid 3456, CALL Index D39002, 88/07/06.

[13]Kelly, 24 Jan 90.

[14]ALLMIS 60, CALL Index D00052, 85/11/04; 2461, CALL Index D00175, 87/01/12; and 1004, CALL Index 851005, 85/11/03.

[15]Kelly, 24 Jan 90.

[16]ALLMIS, 4473, CALL Index 230242, 89/01/26; 3396, CALL Index D40027, 88/04/13; and 3389, CALL Index D40019, 88/04/11.

[17]US Army, ST 100-9, The Command Estimate (1989): 4-4.

[18]ALLMIS 4526 CALL Index D60020 89/02/02.

[19]Ibid 1560, CALL Index D00072, 86/03/18

[20]Ibid 4471, CALL Index 88/01/26.

[21]Kelly, 24 Jan 90.

[22]ST 100-9 (1989): 6-1.

[23]Kelly, 24 Jan 90.

[24]Tichenor, 22 Jan 90.

CHAPTER 6

ANALYTICAL DECOMPOSITION OF THE COMMAND ESTIMATE

This chapter uses techniques of systems analysis to perform a decomposition of the way information is processed and used within the command estimate. Data flow diagrams (DFDs) are used to illustrate this examination. Each component of the command estimate is analyzed from a standpoint of what it does and a determination is then made of whether the use of a rule-based expert system can enhance the performance of that component to assist the commander and staff in its execution.

The command estimate is a continuous process comprised of several interrelated sub-systems. These sub-systems have no fixed starting or stopping points. The relationships and dependencies which these sub-systems have with one another are based on the criticality of the information which must pass from one system to another. The relationships are affected by the time available to conduct the command estimate.

Student Text (ST) 100-9 depicts the command estimate as a cleanly defined system flow chart that follows a linear structure.[1] Figure 3 represents the command estimate as shown in ST 100-9. This diagram shows the control flow of the major events in the system but does not represent the flow of information through the system. Taken literally, the diagram of the command estimate conveys that a mission enters the system, is processed through each sub-system, and then emerges as an operation order (OPORD) or a fragmentary order (FRAGO). Unfortunately, many commanders and staffs attempt to execute the command estimate as depicted in individual and discrete steps. They fail either because they cannot efficiently manage the information, a shortage of time does not allow for the command estimate to be followed, or the situation does not fit the command estimate model. This failure in executing the system does not allow them to make intelligent and timely battlefield decisions.

MISSION

ST 100-9 defines mission as a statement of the job to be performed by a unit. It establishes the information of WHO, WHAT, WHEN, WHERE, and WHY of an operation.[2]

The mission is the initiation point for conducting any iteration of the command estimate. As such, it is a source of information and is either received from a higher

THE COMMAND ESTIMATE

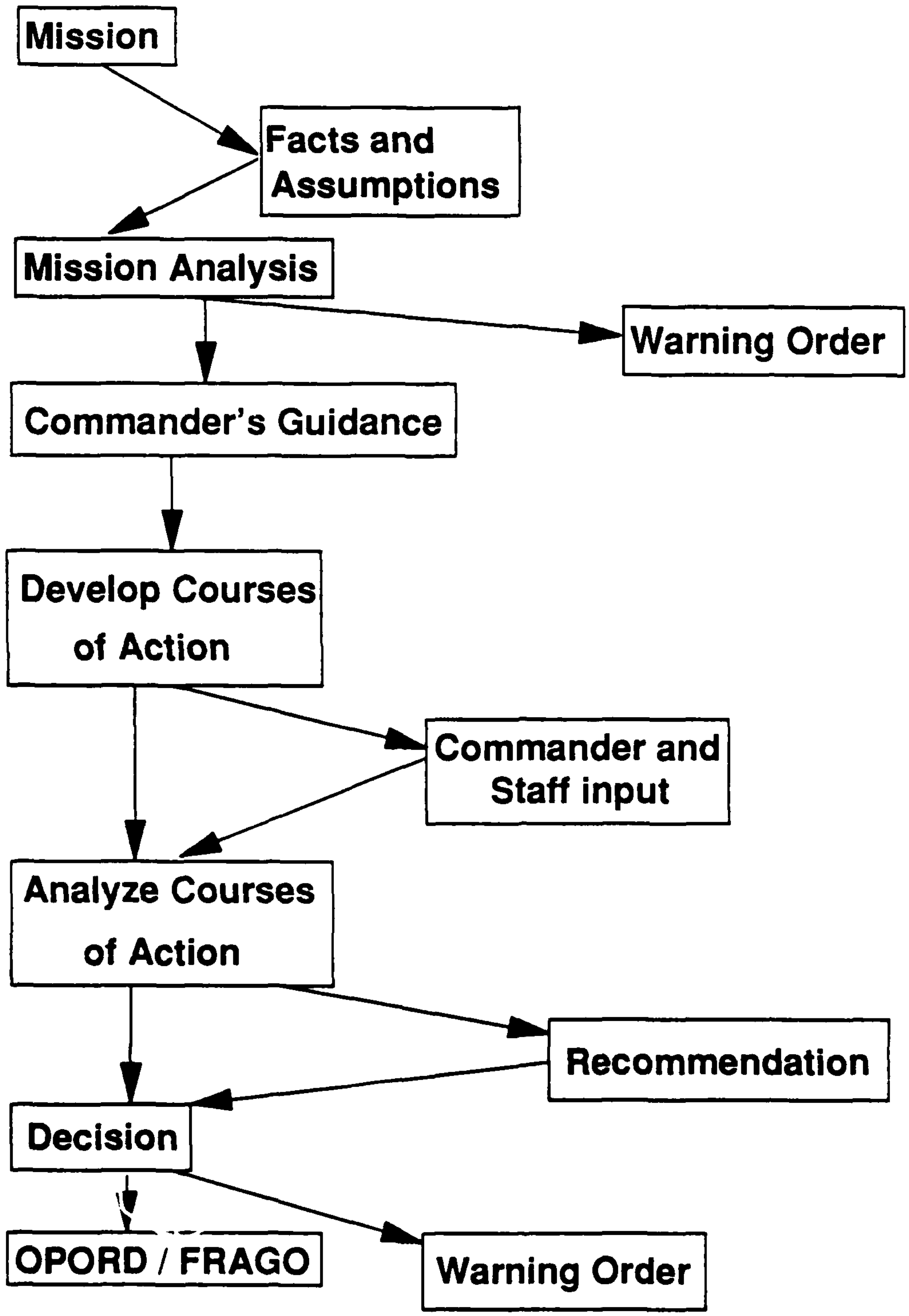

Figure 3.

headquarters or is determined by the commander based on deduction from the current operation. Figure 4 contains DFD 1.0 which is the decomposition of the mission. The mission is filtered and a rough validity check is made to ensure the following parameters are satisfied:

1. WHO: The mission must apply to the unit receiving the mission.

2. WHAT: The mission must be within the capability of the unit.

3. WHEN: The time of mission execution must allow adequate time for planning and rehearsal.

4. WHERE: The location of the mission must take place within the unit's area of operations.

5. WHY: The reason for the action must be given if the subordinate units are expected to produce actions in consonance with the force as a whole.

Missions that do not satisfy the parameters above are rejected until they can be clarified or until the unit is provided the resources to accomplish the mission. Once the mission is validated, the information is transformed into a data store where it is maintained for future processing.

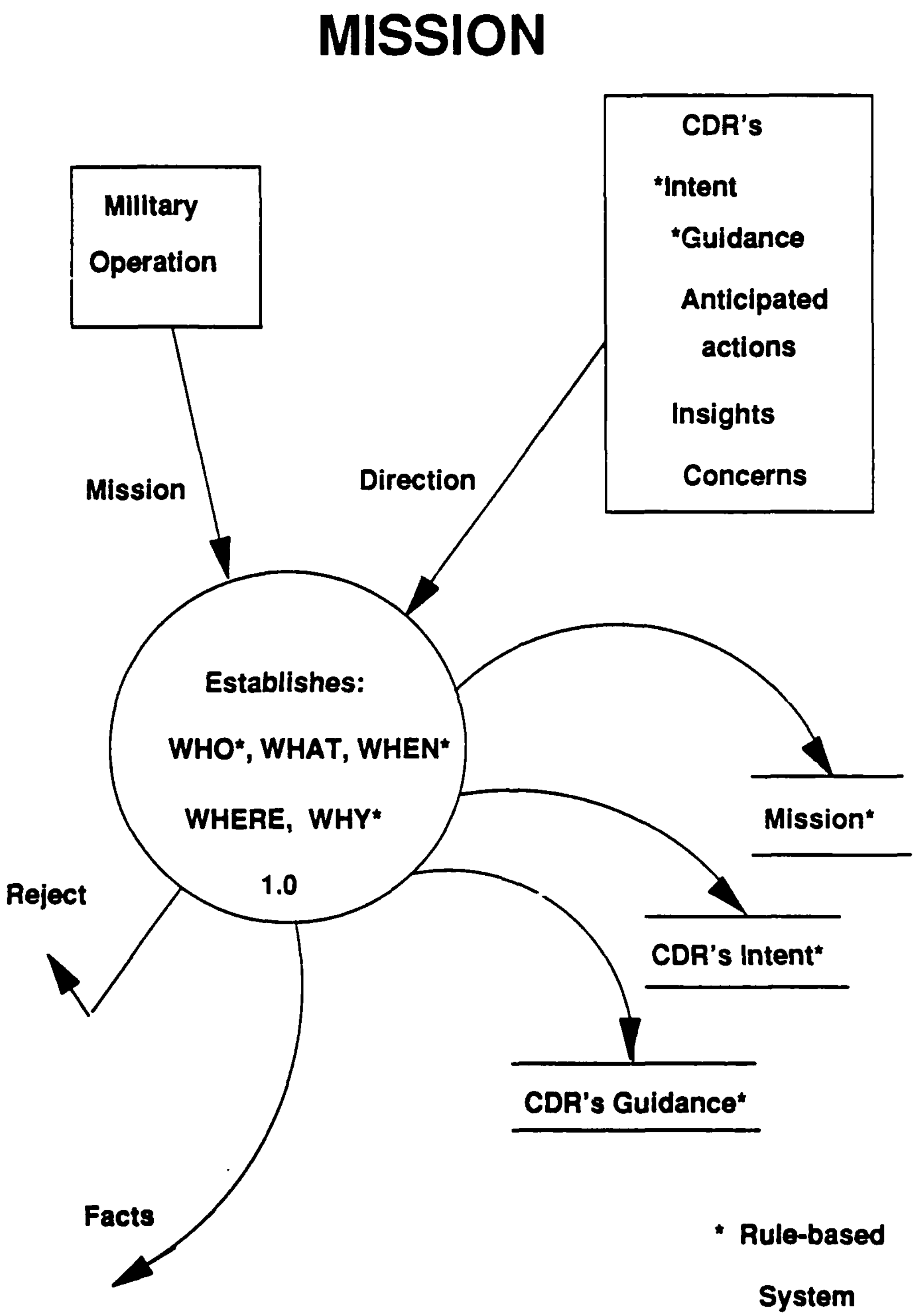
MISSION
CDR's
*Intent
*Guidance
Anticipated
actions
Insights
Concerns
Military
Operation
Mission
Direction
Establishes:
WHO*, WHAT, WHEN*
WHERE, WHY*
1.0
Reject
Mission*
CDR's Intent*
CDR's Guidance*
Facts
* Rule-based
System

Figure 4.

A rule-based expert system could assist the commander and staff by insuring the mission information conveys the following:

1. WHO: A rule-based expert system can track the forces available, their statuses, and indicate exceptional capabilities. This is readily applicable to a rule-based system that can assimilate a broad range of forces, equipment capabilities and doctrines with respect to the commander's intent.

2. WHAT: A rule-based system could ensure that the verbiage is normalized so the expression of WHAT is expressed in doctrinally correct terms. It could also cause an alert if the mission is outside of the unit's capabilities.

3. WHEN: A rule-based expert system can assist the commander in the synchronization of battlefield operating systems by ensuring that an achievable time line is established. It would allocate time to the headquarters and to subordinates based on either the time ratio directed by the commander, or the traditional 1/3 - 2/3 rule where the headquarters is given 1/3 of the available time to plan for the mission and subordinate units are given the remainder.[3] This system would maintain rules and time models for various battlefield activities such as barrier construction, mine field emplacement, bridge erection, administrative and tactical

movement of units, etc., for correct time sequencing and battlefield integration.

4. WHERE: The location for mission execution is critical to space-time synchronization. The area of logistics is severely impacted by this relationship. A rule-based system could determine fuel and transport requirements and assist in transportation management. It would also coordinate maps and other geographical data for mission planning and execution.

5. WHY: In many military endeavors, the WHY is often the most important element of information. Much like the commander's intent, it conveys an image of the "big picture." If the WHY is not clear in the commander's intent, it should be reclarified or separately conveyed and distributed. A rule-based system can ensure that the WHY is normalized to doctrinally correct terms.

Another critical element of mission information is the explanation of the higher commander's intent. This is an information source and forms the basis of the commander's intent at the level receiving the mission. The commander's intent, mission, and commander's guidance are transformed into data stores and will be used in later processes. The data store that is the commander's intent is the master plan that contains the expression of the commander's tactical image of the battlefield at the end of the operation. Closely related to the intent is the

commander's guidance which contains mission information that is not included in the mission statement or commander's intent.

A rule-based system could assist in the expression of the commander's intent, commander's guidance, and mission statement by normalizing the verbiage and accompanying graphics to doctrinally correct expressions. It would also monitor and manage the dissemination of this information to ensure all participants had received it. The result would be that the information would be understood by all participants.

Some of the information that influences the establishment of the mission parameters does not readily lend itself to rule-based expert system assistance. This includes the commander's insights, concerns, and anticipated actions. Due to the cognitive level of these insights, concerns, and anticipations, it is best if this information is left to the commander to develop and convey to subordinates.

FACTS AND ASSUMPTIONS

After receipt of the mission and the higher commander's intent, each staff section generates factual information of the state of their respective areas. These information sources provide a quick status summary to ascertain if the proposed operation can be supported. DFD

FACTS AND ASSUMPTIONS

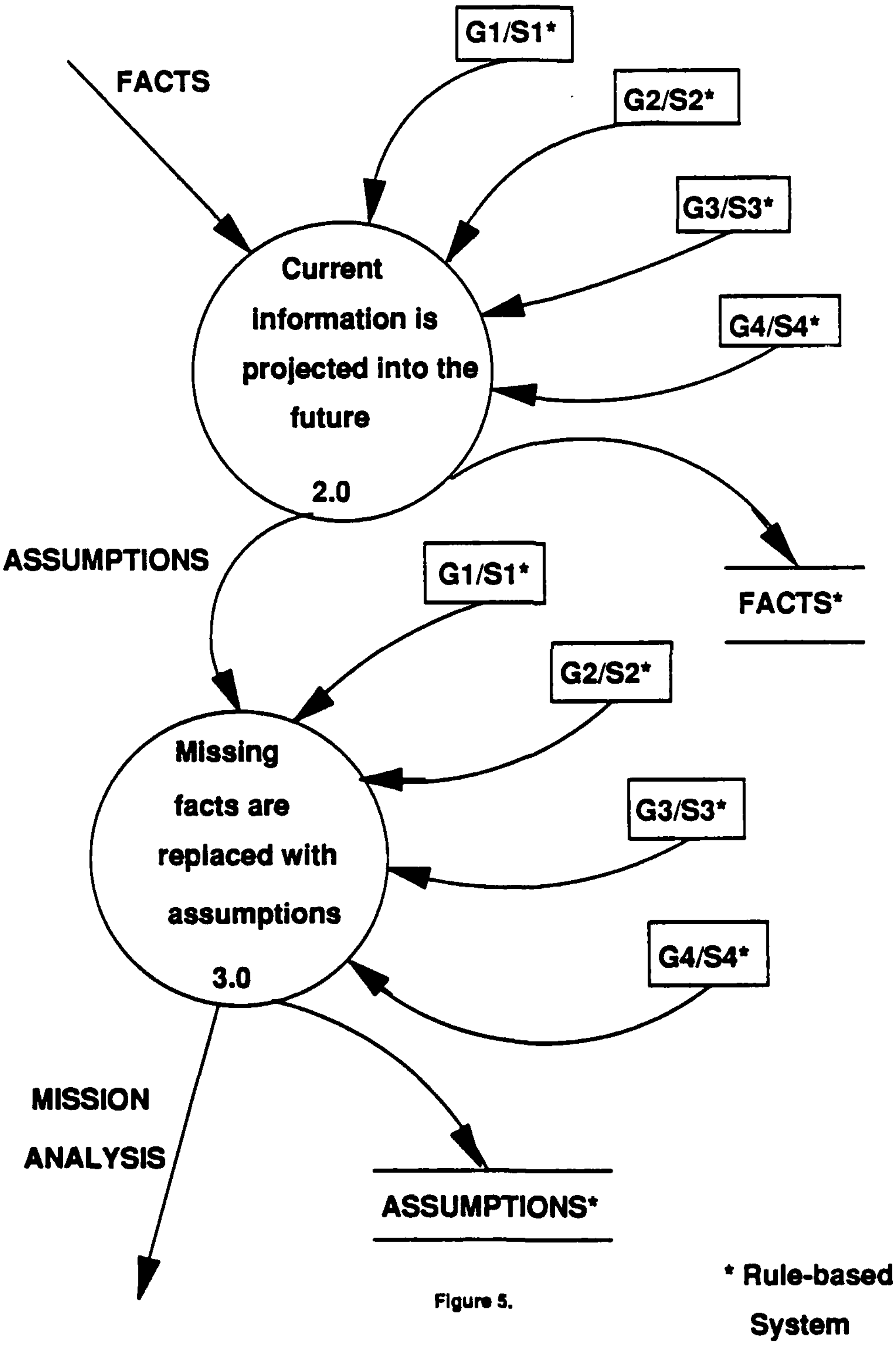

Figure 5.

2.0 found in figure 5 demonstrates the flow as the following categories of facts serve as information sources:[4]

1. G1/S1 provides a current report on the personnel status, morale, and administrative posture of the organization.

2. G2/S2 provides an analysis of the battlefield area measured in depth, width, height, and time; both an operational and tactical view of the terrain; current weather; and known enemy information. The specific process performed by the G2/S2 is called the intelligence preparation of the battlefield (IPB). It is a systematic and continuous process of analyzing the enemy, weather, and terrain in a specific geographical area.[5]

3. G3/S3 conducts the majority of the synthesis of the information. This includes:

a. Mission and commander's intent (one and two levels higher).

b. Current task organization (two levels down).

c. Current unit status This will normally address the combat power, combat support posture, and combat service support capabilities. The result will be a rating of mission capability.

d. Sister service combat support.

e. Other unit information such as locations, status, and mission of flank units, uncommitted units, higher headquarters, and supporting units.

f. Time lines and other synchronization data.

4. G4/S4 provides an accurate and current assessment of the logistic situation of the organization to include subordinate, attached, and other supporting units. FM 101-5 provides a format for this information which is contained in the logistics estimate.[6] It includes:

a. Maintenance capabilities.

b. Status of all classes of supply.

c. Services available to support operations.

d. Transportation assets and capabilities.

e. Available labor for general efforts.

f. Facilities and construction capabilities.

g. Other capabilities available to the force.

5. G5 provides civil affairs and nuclear/chemical weapon preclusion data. This was not depicted in the DFD.

Assumptions are processed as shown in DFD 3.0 in figure 5. The purpose of these assumptions is to replace missing, but necessary, facts. These assumptions will also be used if current factual information is subject to change due to time-event sensitivity.[7] Assumptions serve as information sources in the following areas:

1. G1/S1 will assume personnel factors for each course of action. These include:

a. Critical MOS shortages.

b. Replacement flow.

c. Medical evacuation and hospital support.

d. Human factors such as morale.

2. G2/S2 will make assumptions about:

a. Terrain and weather.

b. Enemy capabilities and vulnerabilities.

c. Friendly capabilities and vulnerabilities.

3. G3/S3 will make assumptions about friendly forces and the general capability to conduct the operation:

a. Status of maneuver, combat support, and combat service support units.

b. Electronic Warfare support.

c. Aviation support.

d. Time.

4. G4/S4 discusses significant differences in the current and anticipated logisitical capabilities.

The amount of facts and information that the staff has to manage is massive. In many instances, the facts that have to be provided to the commander are derived from manual calculations which could easily be automated. Additionally, many of the items of information on which the various staff estimates are based are time sensitive.

A rule-based assistant would greatly enhance the ability of the staff to filter information and maintain the data stores of facts and assumptions. This system would prompt various staff sections for updated information and would strive to replace assumed data with fact as it became available

MISSION ANALYSIS

Mission analysis is the most information management intensive portion of the command estimate. It processes information given in the mission statement, facts, assumptions, the commander's intent at the present and two next higher levels, and the commander's initial guidance. These elements are synthesized into a developed and focused mission statement. Figures 6 and 7 present the DFD decomposition of this process.

The primary inputs are the higher commander's intent, the mission statement, derived facts and assumptions as identified in the mission process. The first transformation of this information is shown in DFD 4.0, figure 6. Here, the identification of the specified and implied tasks occurs. Specified tasks are those tasks that are clearly specified in the mission received. Implied tasks are those tasks that are not specified but are deduced as necessary to accomplish the overall mission or to satisfy any of the specified tasks. This deduction

MISSION ANALYSIS

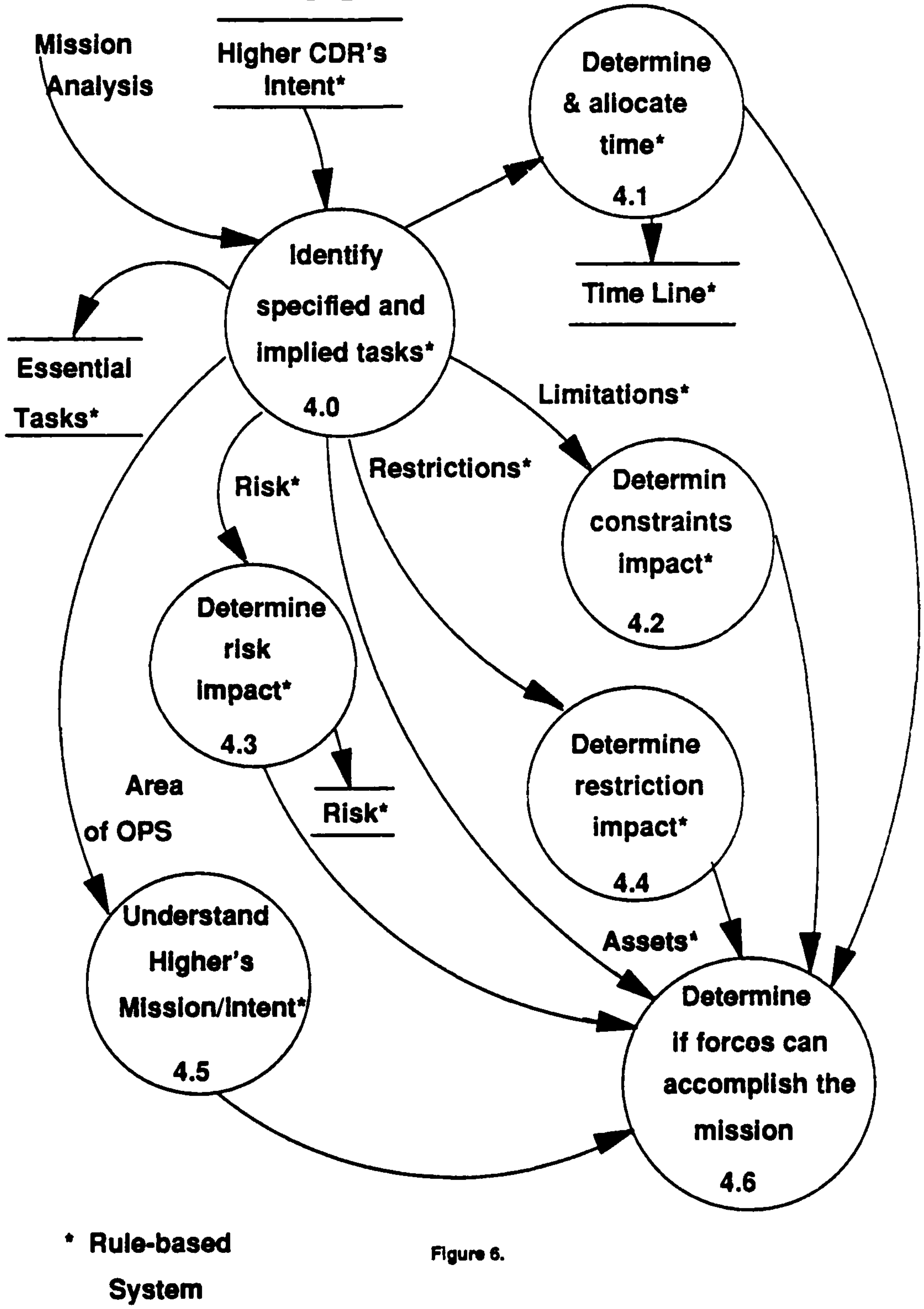

Figure 6.

is accomplished by analysis of the order and analysis of the elements of the tactical situation.[8] An immediate product of the identification of the specified and implied task is the identification of essential tasks that becomes a data store for later use. Essential tasks are those that must be accomplished to complete the overall mission. To properly do this, the staff must understand the intent of their immediate commander and the intent of the commanders two levels up. In conjunction with the essential, implied, and specified tasks, the commander's intent is again analyzed in DFD 4.5 to insure that it is understood and the derived tasks support its accomplishment.[9]

The function of a rule-based system to provide assistance in the process of understanding the commander's intent would be the same as outlined in the mission process (DFD 1.0, figure 4). It would be used to normalize the graphics and verbiage with correct doctrine to insure that what the commander intends for the forces to accomplish is accurately portrayed to subordinates. Additionally, assistance would be given to the identification and maintenance of essential tasks. An expert system could insure that all battlefield operating systems are considered and that staff elements were kept informed of their status.

After the essential tasks to the mission are determined, the information goes through several parallel transformations to determine the impact of time, constraints, risk, and restrictions. These remaining parallel transformations are ideal candidates for assistance using rule-based systems. Figure 6 depicts these transformations.

An initial time line is created as a data store in DFD 4.1, figure 6. This forms the basis of synchronization for mission planning and execution. The most significant area of assistance that a rule-based expert system can give to the command estimate is time management. It could perform this function by determining the time available and generating time tables to sequence planning at headquarters and unit level, manage time-distance calculations based on equipment capabilities and enemy dispositions, assist in the backward planning process, monitor staff and subordinate unit progress, and orchestrate the flow of information between staff elements.

Constraints, as shown in DFD 4.2, figure 6, are those things that a higher headquarters requires to be done. These constraints are limitations to the actions of the subordinate commander. They can be normalized and disseminated to all staff sections by a rule-based system. This will insure that these constraints are understood and

can be planned into the mission.

Risks are shown in DFD 4.3, figure 6. They can be generated from any staff area input that indicates friendly forces may not meet desired parameters such as desired levels of supplies, quantitative superiority in forces and equipment, intelligence of enemy capabilities, etc., to meet possible enemy courses of action. A rule-based system could monitor these areas of risk and prompt planners to address them before developing statements of mission and intent. Restrictions and other limitations can be handled in the same manner.

The ability of a rule-based expert system to assist in the management of risk, constraints, and restrictions will allow the commander and staff to better shape the mission planning for optimum results.

The resulting information from these transformations is used to determine if the available forces can accomplish the mission. This process is shown in DFD 4.6, figure 7. A tentative task organization is produced from the available forces and a rough estimate is made to determine if the forces are sufficient to accomplish the mission. It is at this point that the commander makes a decision based on the results of the mission analysis. If he approves the identified essential tasks, he will provide the restated mission as shown in DFD 4.7, figure 7. This mission statement is dynamic and

MISSION ANALYSIS

(Continued)

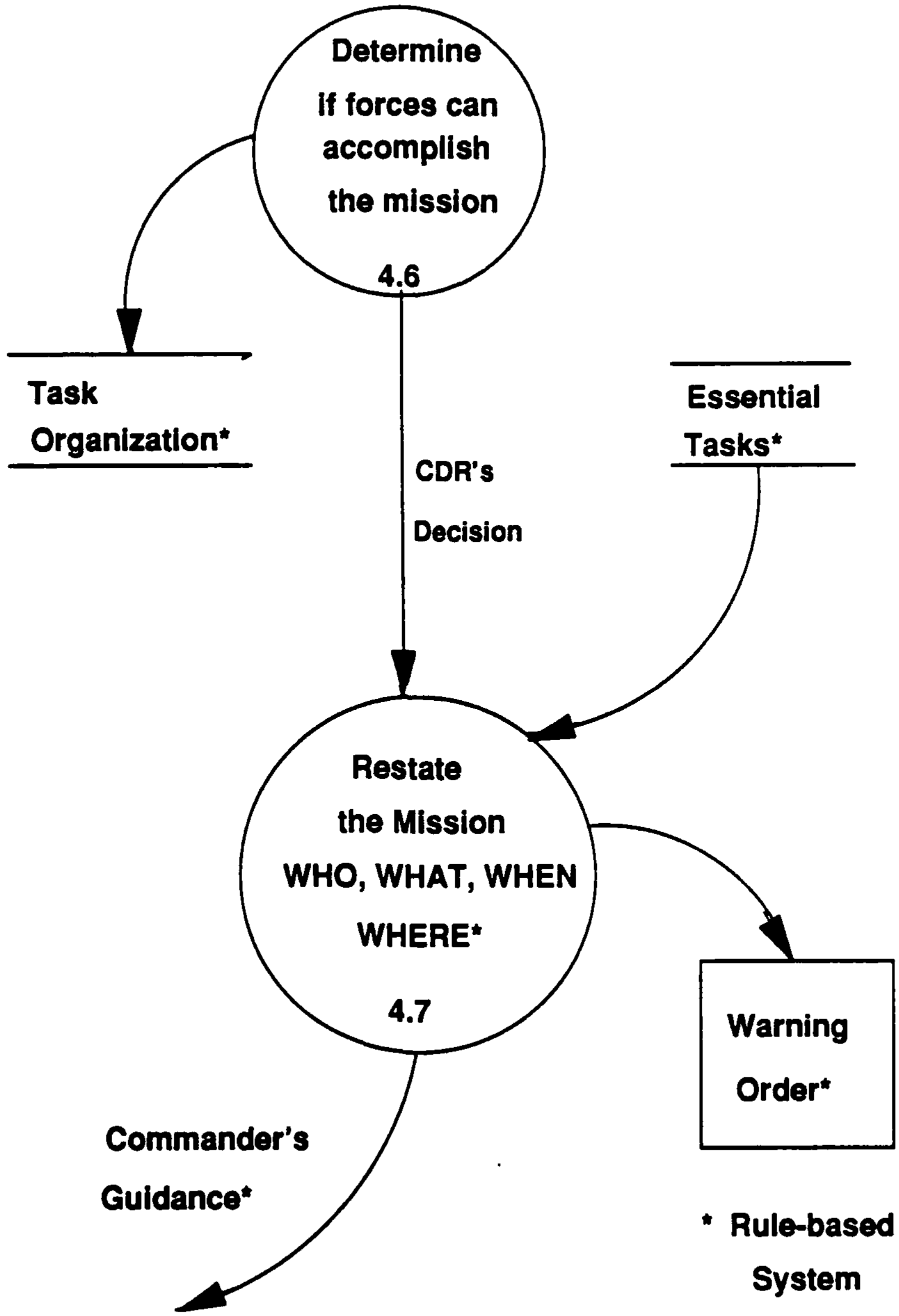

Figure 7.

is sensitive to the identification of other essential tasks. Once approved, the mission analysis and restated mission form the basis for the warning order and provide focus for course of action development.[10] The warning order represents a data sink, or an information output, and is the first time information formally leaves the command estimate.

Automation can assist in the initial calculation of force ratios and the development of a task organization based on forces available and the enemy. A rule-based system can further refine this process by determining force capabilities based on combat intelligence (facts) and projections (assumptions).

The restated mission will contain the WHO, WHAT, WHEN, and WHERE from the mission statement. This is a noticeable change from the mission process (DFD 1.0, figure 4), because it no longer contains the WHY. The product from the restated mission is the warning order which explains the WHY.

Assisted with a rule-based expert system, the restated mission would go through the normalization process to ensure that it used the proper graphics and technically correct vernacular to convey the commander's intent. It would also address the appropriate battlefield framework. Finally, the warning order would be

disseminated by the rule-based system insuring it sent to and received by the appropriate units.

COMMANDER'S GUIDANCE

Although the commander will provide planning guidance to his staff and subordinates as often as necessary, it is critical after the restatement of the mission. This guidance will provide the staff with a better understanding of the commander's image, or mental model of the situation he wants translated into action by the staff.[11] The guidance, coupled with the restated mission, will reinforce the commander's intent and produce the starting point for the development of courses of action. Figure 8, commander's guidance DFD, examines the process of formulating the planning guidance.

Several data stores effect the process of formulating planning guidance. These are the commander's intent, risk, and the time line. The commander's intent was developed in the mission process (DFD 1.0, figure 4) while the components of risk and time line have their genesis in the mission analysis process (DFD 4.0, figure 6). It should be noted that all these data store are constantly being refined and updated. Additionally, the commander will define specific courses of action that he desires to have developed. The time line is displayed as both an input, from the mission analysis process (DFD

COMMANDER'S GUIDANCE

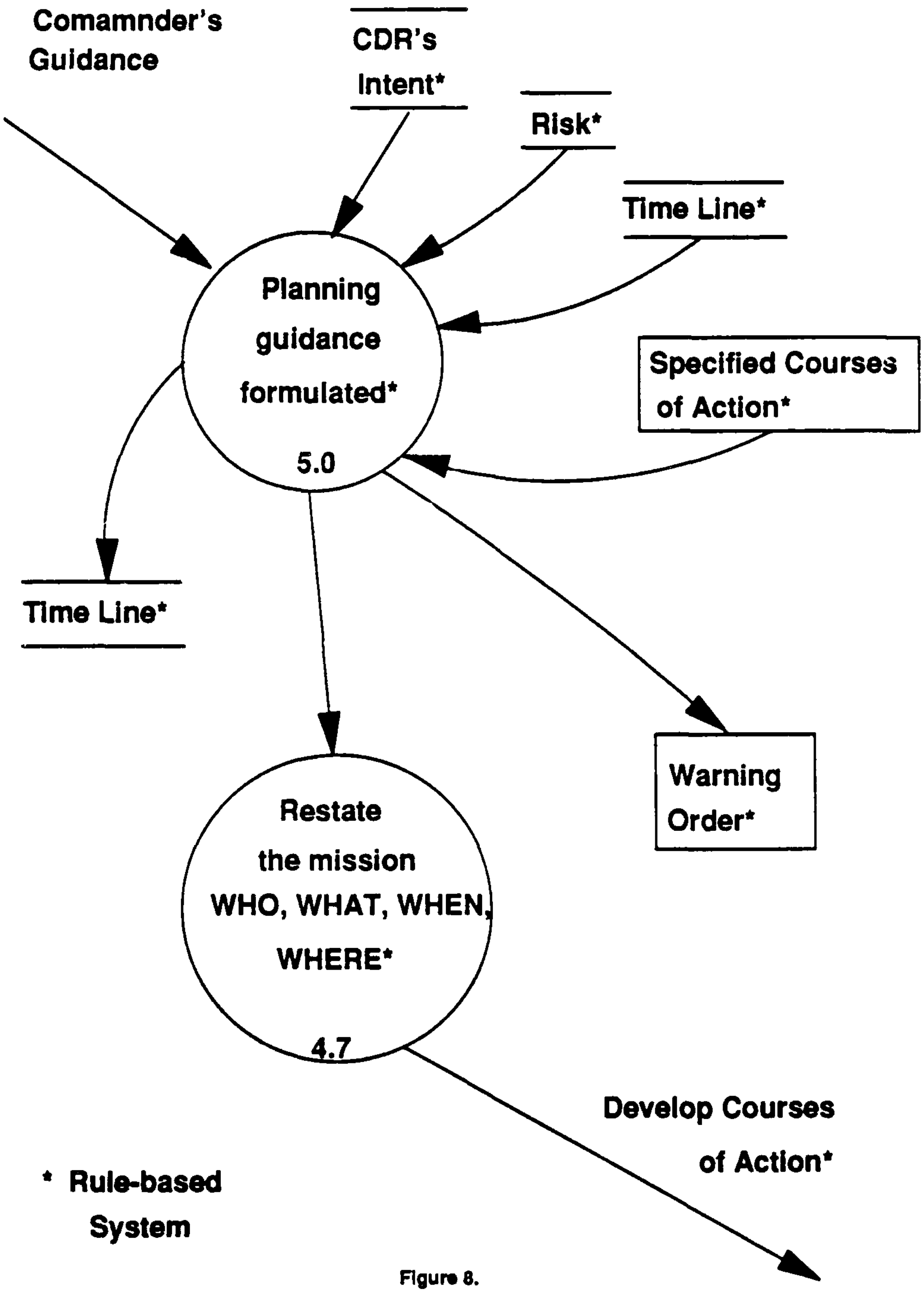

Figure 8.

4.0, figure 6), and as an output because the commander formally announces the time for the course of action briefing. This time line may be different than initially generated in the mission analysis process. Another output is the warning order. It is identical to the warning order issued during th mission analysis process (DFD 4.7, figure 7) but may contain updated information.

The end state of the commander's guidance is formal presentation of the restated mission. It should be noted in figure 8 that the process for this is labeled the same (DFD 4.7) as that found in the mission analysis process in figure 7. The mechanics are identical. If there are no changes, the restated mission is the same entity as defined in the mission analysis process.

The entire process of the commander's guidance, less the commander's declaration of specific courses of action, is a candidate for assistance from rule-based expert systems. The time line and warning order outputs are the same as described in the mission analysis process and will be the same entities if there are no changes.

At the conclusion of this process, the staff will continue collecting and processing information and will begin developing of courses of action.

DEVELOP COURSES OF ACTION

Developing courses of action (COA) to accomplish the mission is military art bound by military science. The key to developing COAs is to release imagination and creativity during "brainstorming" by the commander and G3/S3.[12] COAs must be feasible and have to be capable of accomplishing the assigned mission. Any COA that is determined not to be feasible is immediately rejected.

There is no rule-of-thumb for the exact number of COAs to develop. If time permits, several COAs should be generated for each likely enemy COA as determined by the G2/S2 in the IPB. The total number of courses of action must be manageable.

A proposed COA must be significantly different from any others. Significant difference is normally identified in one of the following areas:[13]

1. Use of reserve forces.
2. Task organizations.
3. Location and purpose of main effort.
4. Scheme of maneuver.
5. Defeat mechanism.

After a COA is proposed, the commander and staff perform several information transformations to assimilate available information, the mission, the commander's intent, and the application of doctrine. The steps in the method to synthesize this information are:[14]

1. Analyze relative combat power.

2. Array initial forces.

3. Develop the scheme of maneuver.

4. Determine command and control means and maneuver control measures.

5. Prepare COA statement(s) and sketch(es).

The key inputs for developing courses of action are the DFD process of IPB, data stores containing the facts, assumptions, task organization, essential tasks, the time line, and mission. These data stores provide the WHO, WHAT, WHEN, WHERE, HOW, and WHY for the development of the courses of action. This information is generated in other processes of the command estimate and are maintained as data stores until needed. Figure 9 depicts the flow of this information into the process to determine possible courses of action (DFD 6.0). The IPB is a distinct and separate process from the command estimate. It is not functionally decomposed in this chapter. Facts and assumptions are generated in DFDs 2.0 and 3.0, figure 5. Task organization, essential tasks, and the time line are developed during mission analysis in DFDs 4.0, 4.1, and 4.6, figures 6 and 7. Additionally, the time line information was further processed in DFD 5.0, planning guidance formulation, figure 8.

Each of the inputs is a candidate for assistance by rule-based expert systems. The data stores have been

DEVELOP COURSES OF ACTION

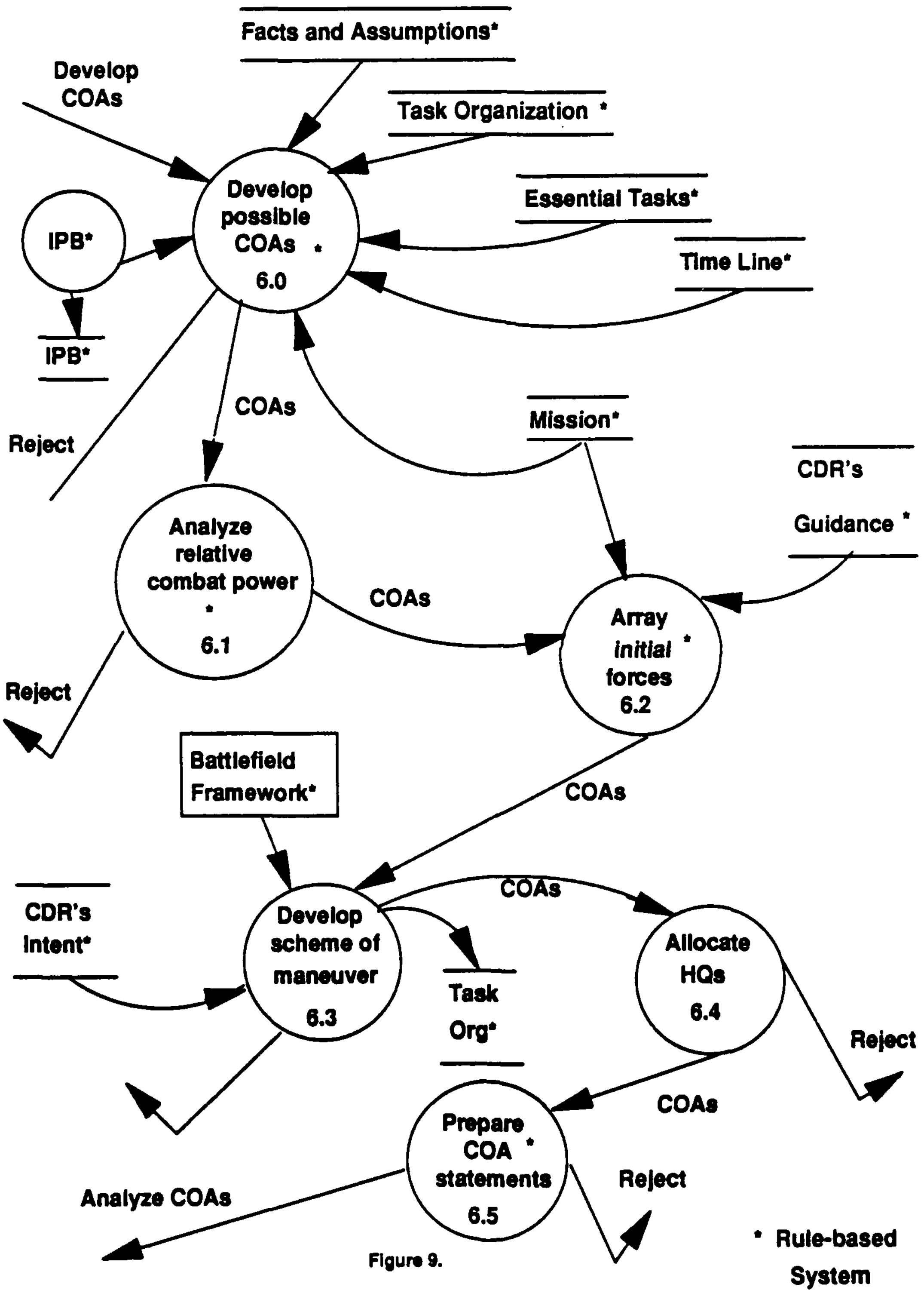

Figure 9.

discussed with the process from which they originated. The intelligence preparation of the battlefield (IPB) is discussed in a later section. Although all the inputs into the process of determining possible COAs can be assisted with rule-based systems, the creative act of developing the possible COAs should be a human performed process with minimal coaching or assistance.

After the COAs have been determined, the information is processed to analyze the relative combat power of friendly versus enemy forces (DFD 6.1, figure 9). This is currently a quick computation of rough ratios using arbitrarily assigned comparison values. The purpose is to give a "feel" for relative strengths and is not for absolute comparisons. The result provides for some general conclusions about the type of operations that can be conducted.[15] If this rough model depicts an untenable COA, it will be rejected at this point.

The ability of a rule-based expert system to provide a greater depth of empirical detail in this process is apparent. An automated system could calculate detailed information for both friendly and enemy units to produce a much more scientific and accurate picture of the opposing forces.

The COA is now ready to have forces arrayed to represent the necessary troop dispositions. This is a

graphical map-based exercise that determines the forces needed to accomplish the mission and provides a starting point for the scheme of maneuver. The array of friendly forces is made without regard to task organization beyond what is available by unit types. Inputs for this process are the mission and the commander's intent. The purpose of this step is to provide a notional image of how the forces will appear on the battlefield.[16]

The basis for arraying generic forces is performed using a procedure delineated in ST 100-9:[17]

1. Determine the ratio of forces involved.

2. Determine the size of the units to be arrayed.

3. Determine a proposed LD/LC (offense) or FEBA (defense).

4. Develop the deception story.

5. Make initial array of friendly forces.

Determining the force ratios necessary for the operation and the size of the units and arraying initial forces is a process that has been demonstrated by the AirLand Battle Management (ALBM) system.[18] This should be a rule-based system task within the command estimate. However, the steps of determining the proposed LD/LC or FEBA and developing the deception story should be human performed tasks. Additionally, the inputs of the commander's guidance and mission should be assisted with

rule-based systems. Both of these data stores, and their management, have been discussed in DFDs 1.0, 4.7, and 5.0 in figures 4, 7, and 8, respectively.

The next process is to develop the scheme of maneuver for the forces. This process is the central expression of the commander's image and intent for the battle.[19] It is the zenith of military art within the command estimate. It provides the HOW to the course of action by showing the actual employment of the forces. Subsequent analysis of the COA is dependent upon the scheme of maneuver. Two inputs are primary to this process: the data store of the commander's intent and the data source of the appropriate battlefield framework (offense vs. defense). The acid test for the scheme of maneuver is that it must accomplish the commander's intent.[20] If it does not, the COA is rejected.

Like arraying initial forces, the process of developing the scheme of maneuver is highly cognitive and does not fit the model for assistance with a rule-based system. However, it can be assisted in the effort to determine if the doctrinal tenets of the battlefield framework have been adequately addressed.

Command and control means and maneuver control measures are allocated in the next process (figure 9, DFD 6.4). This is a two-fold process to insure a proper span of control exists by allocating headquarters assets to

each maneuver unit and that appropriate battlefield geometry is applied to control the fire and maneuver of those units. If any maneuver units cannot be adequately organized under the control of a headquarters element, or command and control cannot be established, the COA will be rejected. This process does not lend itself to effective assistance with rule-based systems.

The final transformation of information with respect to develop COAs is to prepare course of action statement(s) and sketch(es). This is the responsibility of the G3/S3 and will contain the WHAT, WHEN, WHERE, HOW, and WHY of the mission. The combination of a statement and a sketch must convey a clear image of the HOW for a unit to accomplish a given mission. It is expressed in standard military graphic symbols and operational terms. If, at this point, a COA is detected as being either not feasible or fails to accomplish the commander's intent, the COA will be rejected. This process lends itself readily to rule-based expert system assistance. The primary focus would be to insure that graphics and terms were doctrinally correct.

COA ANALYSIS

After the COAs are developed and sketched, they are analyzed by the staff to identify the best COA to recommend to the commander. This analysis must be done

promptly and efficiently. Any item of information developed by one staff element that might effect another's must be surfaced immediately.[21] The premier event of this analysis is the conduct of the war game. Figure 10 decomposes the flow of information during the process of analyzing COAs.

The first transformation of information occurs when the G3/S3 briefs the staff about each course of action (DFD 7.0, figure 10). During this brief, if a COA is identified as not being feasible by any staff member, it is immediately rejected. After the courses of action are briefed, a determination is made on which courses of action will be war gamed (DFD 7.1). The inputs to this decision are the IPB and the G3/S3 assessment. The management of these inputs could be assisted by a rule-based system.

ST 100-9 states that at this time, the process of war gaming begins by each staff sections.[22] However, before the actual war gaming phase can begin, several processes must occur to insure the staffs are working with good information. It is essential that the proper forces are considered and the critical events identified.

In DFD 7.2, figure 10, assumptions must be validated or replaced by facts. These assumptions were identified in DFD 3.0, figure 5. Any COA depending on assumptions that are no longer valid and cannot be

COA ANALYSIS

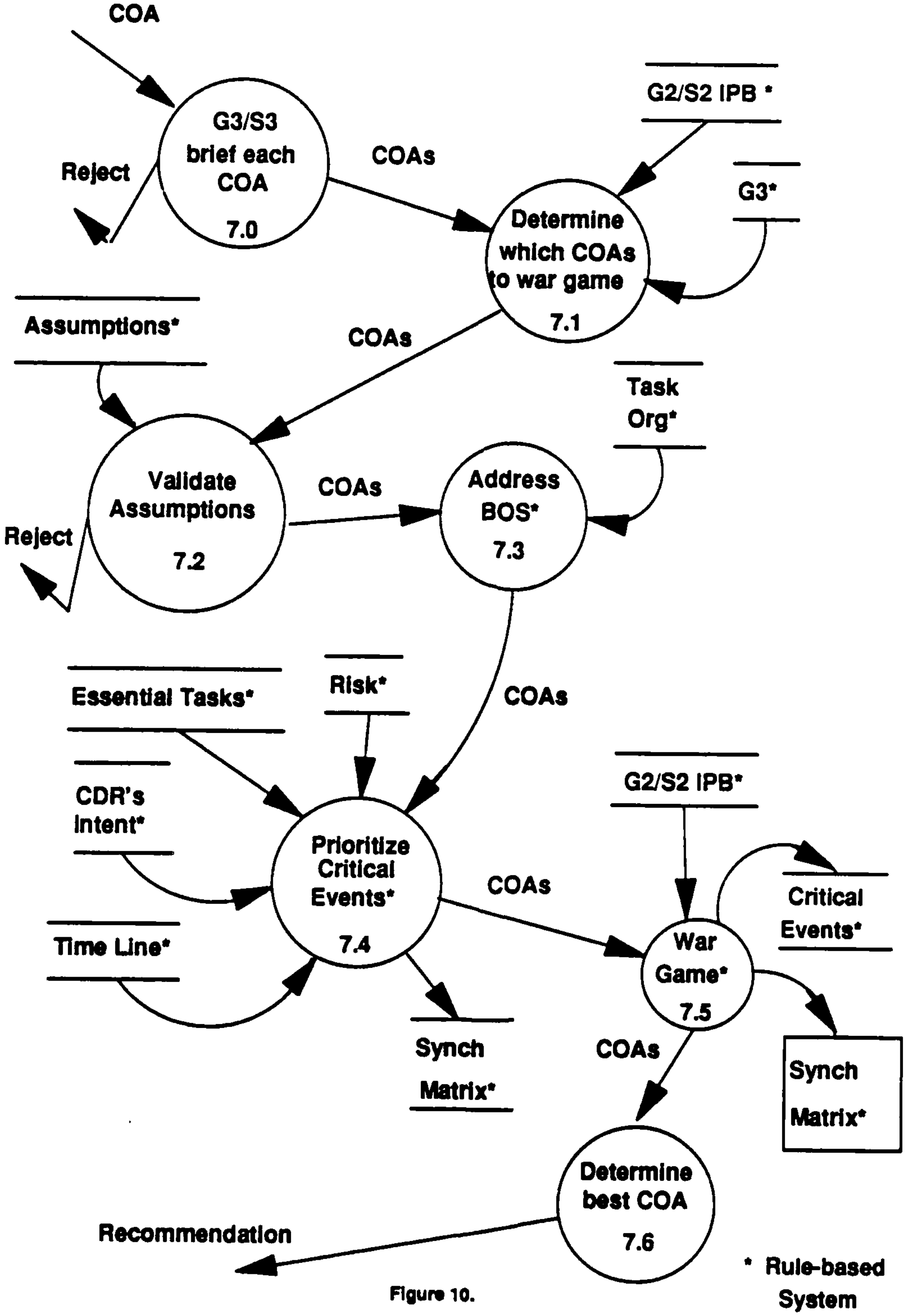

Figure 10.

replaced by reliable fact will be rejected. The COA must then be audited to insure that the BOSs have been adequately addressed as shown in DFD 7.3, figure 10. The task organization that was developed in DFD 4.6, figure 7, and refined in DFDs 6.0 and 6.3, figure 9, is the major input. Maintenance of the task organization is well suited for assistance with a rule-based system. The process of filtering the COA through a mechanism to insure that the BOSs have been adequately addressed is well suited for a rule-base expert system. It should be noted that failure to include or adequately address a BOS is not grounds to reject the COA. However, it would be the responsibility of the rule-based system to bring this omission to the attention of the commander and staff.

The prioritization of critical tasks is depicted in DFD 7.4, figure 10. Is is accomplished by processing data store information of essential tasks (DFD 4.0 and 6.0), commander's intent (DFD 1.0, 4.0, 5.0, and 6.3), time line (DFDs 4.1, 5.0, and 6.0), and risk (DFDs 4.3 and 5.0). An output is a data store establishing a synchronization matrix which is developed from integrating the BOS into the time line. This process is a viable candidate for assistance with rule-based systems since all inputs and the output are data stores that lend themselves to automation.

In the current manual implementation of the command estimate, the war game is conducted abstractly and does not use much scientific technique. It is a mental exercise that relies on the experience of the war gamer. DFD 7.5 in figure 10 displays the inputs into the war game as the COAs and the interplay with the G2/S2 IPB. The outputs include a synchronization matrix, and a data store of critical events. While the synchronization matrix is an easy function to automate using a rule-based system, the process of identifying critical events should be a human function. Once identified by the staff, the management of critical events would be done by a rule-based system that would collate the essential tasks indentified in DFD 4.0, figure 6. The sub-components of the war game will not be decomposed in this study. Instead, the entire war game process should be considered for replacement by a rule-based expert system simulation exercise in which enemy and friendly forces are structured and arrayed over a specified piece of terrain. The results of such engagement should be easy to determine and could be conducted rapidly. This will allow for multiple iterations of a COA versus several enemy COAs. A rule-based system would excel at this because it could, using a rule-base of enemy tactics and equipment, closely approximate the reactions of an enemy force.

Upon completion of the war game, the results are

compared in DFD 7.6, figure 10, to determine which COA has the highest probability of success against the most likely enemy COA. This is done by each staff section. The G3/S3 evaluates the results using subjective criteria such as BOS, tenets of AirLand Battle, the military aspects of terrain, etc. The G1 and G4 compare the COAs in terms of how well they can be supported from a personnel or logistics perspective. The commander may specify factors that have a greater precedence over others. This final process of determining the best COA is highly subjective. It should be a human derived process. Rule-based systems for determination of the best COA are not appropriate.

DECISION

The recommendation for the best COA is presented to the commander in the form of a decision brief. It is during this session that the commander formalizes his decision. Figure 11 represents the decision process. DFD 8.0 demonstrates that two inputs are processed along with the recommendation. The first is the mission. The COA must accomplish the mission which began this process. The second input is the higher commander's intent. Again, the COA must meet the criteria of this input. If, by some chance, a COA at this point fails these final tests, it may be rejected. The products of this transformation are the warning order and the decision. The warning order is

DECISION

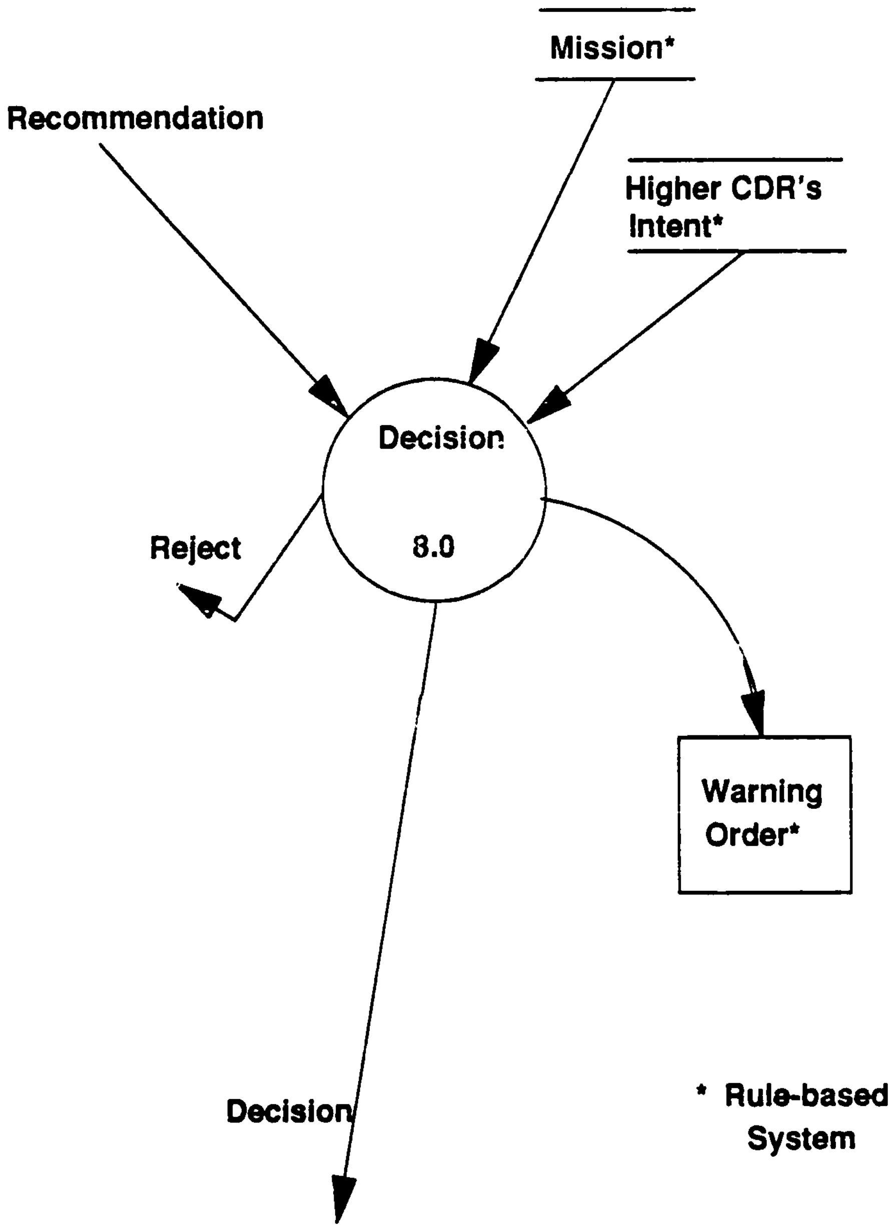

Figure 11.

the same data sink as discussed in DFDs 4.7 and 5.0. Unless changed, it is the same entity.

The input data stores of mission and higher commander's intent have been designated for rule-based systems in several previous DFDs and have been discussed in detail. The actual process of the decision is based on the commander's experience, trust and confidence in his command, and his estimate of the situation. He may agree with the recommendation or reject it and elect an alternate COA. Additionally, he may direct the use of a COA with modifications or one not previously considered. In any event, the commander must refine the COA into a clear decision and then announce the decision and the concept of the operation.[23] The process of making the decision is not appropriate for a rule-based system. However, the warning order is a candidate for using rule-based systems.

OPORD/FRAGO PREPARATION

The operations order (OPORD) or fragmentary order (FRAGO) process relies on several inputs to insure the output is clear, concise, and conveys the intended information. Figure 12 contains the information flow of this process. The primary inputs are the data stores of mission and commander's intent. These provide the WHAT,

OPORD/FRAGO

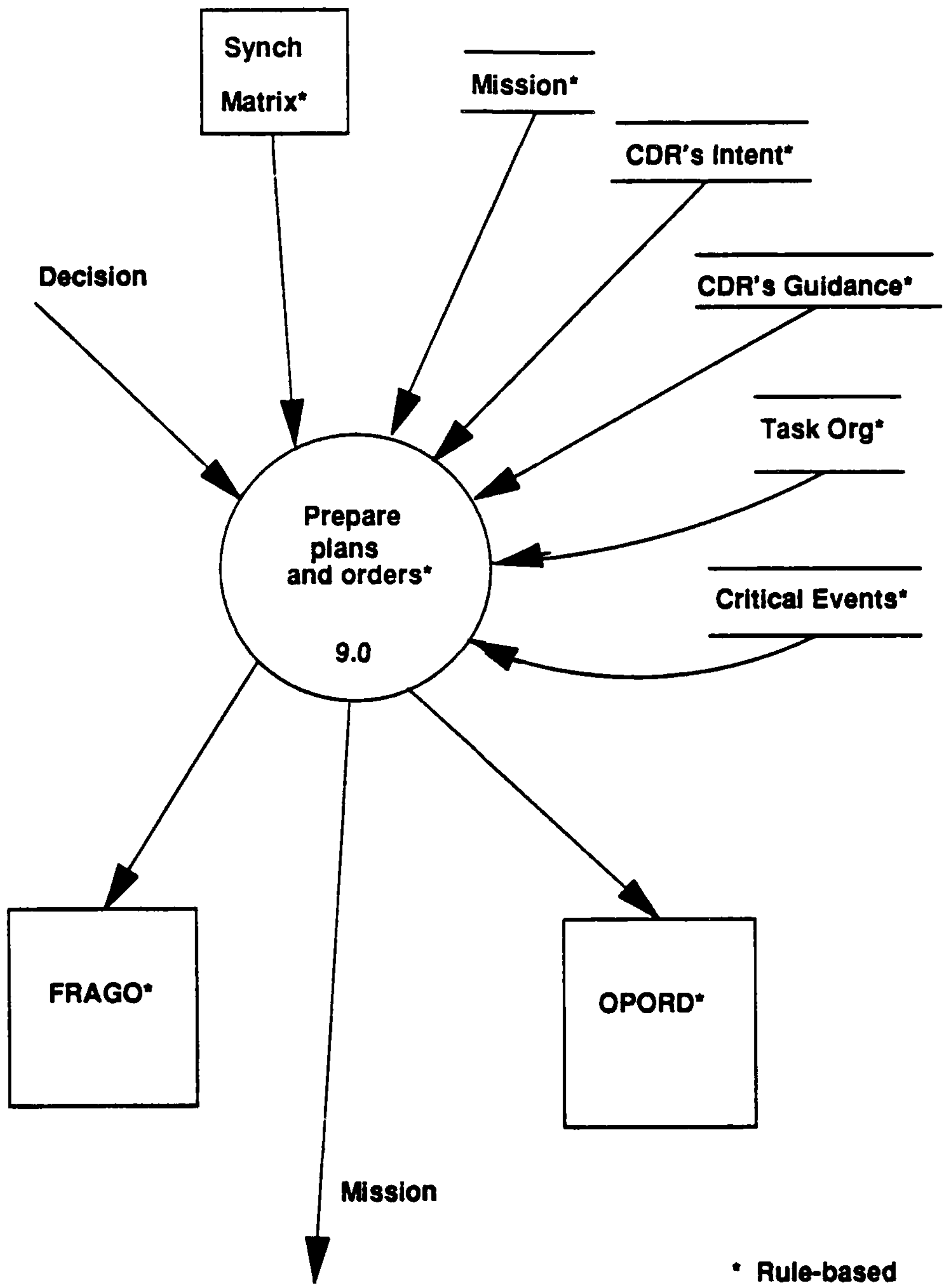

Figure 12.

WHY, and WHERE. These are the same data stores as discussed in DFD 1.0 and have been refined at every process through which they have passed. The commander's guidance is a data store for information that is not contained in either the commander's intent or mission statement but is still germane to the situation. The task organization is the result of the refinement of DFD 6.3 which developed the scheme of maneuver. This data store provides the WHO. The synchronization matrix produced by DFD 7.5 provides the detailed WHEN.

The OPORD/FRAGO will produce a completed HOW for the units to accomplish the mission. To do this, it must:[24]

1. Make maximum use of graphics.
2. Not be unnecessarily redundant.
3. Be concise.
4. Include necessary friendly information.
5. Convey the intent of the commander.

The process of preparing plans and orders should be assisted by rule-based expert systems. It is highly structured and follows doctrinally defined procedures. The inputs of information have been designated as candidates for rule-based assistance.

COMMANDER AND STAFF INPUT

The command estimate sequence of events as outlined in ST 100-9 contains an entity called commander and staff input. As depicted, it only interacts with the processes of "Develop Courses of Action" and "Analyze Courses of Action." with the caveat that this entity should update information, provide the results of reconnaissance, and feed corrected data into the system.[28] This element has not been addressed specifically in the decomposition of the command estimate because this action of input by the commander and staff occurs in every process as information is updated, expanded, and corrected.

SUMMARY

This structured decomposition of the command estimate is intended to show how information flows through the system and to identify those elements that can be enhanced by the use of rule-based expert systems. Table 2 encapsulates these findings and denotes how those processes that would benefit from automated assistance.

Of special interest is the frequency of which some of the information entities appear when the command

estimate was decomposed. The importance of these information entities can be expressed as the number of times that they are used throughout the entire process. The most frequently appearing information entity was the commander's intent. The commander's intent is the common thread that connects all the sub-processes of the command estimate. It is the image of what the commander wants at the conclusion of the operation. This analysis indicates that it is the single most important information element of the command estimate.

The most frequently appearing entities of information are:

1. Commander's intent.
2. Time line and synchronization matrix.
3. Mission statements (See note 1).
4. Task organization (See note 1).
5. Critical events (See note 1).
6. G2/IPB (See notes 1 and 2).
7. Warning orders.

Note 1: The mission statement, G2/IPB, task organization, and critical events appeared an equal number of times as separate information process entities within the decomposition of the command estimate. The priority ranking above is a subjective determination of which entity manages the most critical information.

Note 2: The G2/IPB is integral to tactical

implementations of the command estimate. However, it is a distinct process that should be considered separately. The command estimate is functionally decomposed in appendix A.

CHAPTER 6 SUMMARY

This table is a recapitulation of the information flows analyzed in the command estimate. The following key is used to explain the type of system indicated:

Norm Normalization of an expression or graphic to doctrinally correct form.

Synch Synchronization of action, equipment, or event to a common time reference.

DM Data Maintenance. Data is maintained in a store or data base. The information is constantly updated as changes occur.

Con Consultancy to ensure that doctrine and AirLand Battle tenets are adhered to.

CMP Computational procedures in which the rule-based system determines that a mathematical computation is necessary. It will continually update these computations as changes occur.

PO Prepare output of warning orders, OPORDs, FRAGOs, and related graphics.

DFD PROCESS	DFD	RULE-BASED (Y/N)	RELATED DFD	TYPE OF SYSTEM
MISSION	1.0			Norm
CDR's Intent		Y	4.0,5.0,6.3, 7.4,8.0,9.0	
CDR's Guidance		Y	6.2,9.0	Norm
Anticipated Acts		N		DM
Concerns		N		DM
Mission		Y	6.0,6.2,8.0,9.0	Norm
FACTS	2.0		6.0,7.1	DM
G1/S1		Y		
G2/S2		Y		
G3/S3		Y		
G4/S4		Y		
ASSUMPTIONS	3.0		6.0,7.2	DM
G1/S1		Y		
G2/S2		Y		
G3/S3		Y		
G4/S4		Y		
MISSION ANALYSIS	4.0			
CDR's Intent		Y	1.0,5.0,6.3, 7.4,8.0,9.0	Norm
Identify Tasks		Y	4.7,6.0,7.4	DM

TABLE 2.

CHAPTER 6 SUMMARY
(Continued)

DFD PROCESS	DFD	RULE-BASED (Y/N)	RELATED DFD	TYPE OF SYSTEM
DETERMINE TIME	4.1			
Time Line		Y	5.0,6.0,7.4, 7.5,9.0	Synch
CONSTRAINTS	4.2	Y		DM
RISK	4.3	Y	5.0,7.4	DM
RESTRICTIONS	4.4	Y		DM
UNDERSTAND HIGHER INTENT	4.5	Y	1.0,4.0,5.0, 6.3,7.4,8.0	Norm
DETERMINE IF FORCES CAN ACCOMPLISH MSN	4.6			
Task Org		Y	6.0,6.3,7.2,9.0	DM
RESTATED MISSION	4.7	Y	5.0	Norm
Essential Tasks		Y	4.0,6.0,7.4	DM
Warning Order		Y	5.0,8.0	Norm
PLANNING GUIDANCE	5.0			
CDR's Intent		Y	1.0,4.0,6.3, 7.4,8.0,9.0	Norm
Risk		Y	4.0,4.3,7.4	DM
Time Line		Y	4.1,6.0,7.4, 7.5,9.0	Synch
Specific COAs		N		
Warning Order		Y	4.7,8.0	Norm
RESTATE MISSION	4.7			
Essential Tasks		Y	4.0,6.0,7.4	DM
DETERMINE POSSIBLE	6.0			
IPB		Y	2.0,3.0,7.1,7.5	Perform
Facts & Assump		Y	2.0,3.0,7.1,7.2	DM
Task Org		Y	4.6,6.3,7.2,9.0	DM
Essential Tasks		Y	4.0,4.7,7.4	DM
Time Line		Y	4.1,5.0,7.4, 7.5,9.0	Synch
Mission		Y	1.0,6.2,8.0,9.0	Norm

TABLE 2 (Continued).

CHAPTER 6 SUMMARY
(Continued)

DFD PROCESS	DFD	RULE-BASED (Y/N)	RELATED DFD	TYPE OF SYSTEM
ANALYZE CBT POWER	6.1	Y		CMP
ARRAY INIT FORCES	6.2			
Mission		Y	1.0,6.0,8.0,9.0	Norm
CDR's Guidance		Y	1.0,9.0	Norm
DEVELOP SCHEME OF MANEUVER	6.3	N		
Battlefield Framework		Y		Con
CDR's Intent		Y	1.0,4.0,5.0, 7.4,8.0,9.0	Norm
Task Org		Y	4.6,6.0,7.3,9.0	DM
ALLOCATE HQs	6.4	N		
COA STATEMENTS	6.5	Y		Norm
G3/S3 BRIEF COAs	7.0	N		
DETERMINE COA TO WAR GAME	7.1	N		
IPB		Y	2.0,3.0,6.0,7.5	Perform
G3 Input		Y	2.0,3.0	DM
VALIDATE ASSUMP.	7.2	Y	3.0	DM
ADDRESS BOS	7.3			
Task Org		Y	4.6,6.0,9.0	DM
PRIORITIZE CRITICAL TASKS	7.4			
Essential Tasks		Y	4.0,4.7,6.0	DM
CDR's Intent		Y	1.0,4.0,5.0, 6.3,8.0,9.0	Norm
Time Line		Y	4.1,5.0,6.0, 7.5,9.0	Synch
Risk		Y	4.3,5.0	DM
Synch Matrix		Y	4.1,5.0,6.0, 7.5,9.0	Synch

TABLE 2 (Continued).

CHAPTER 6 SUMMARY
(Continued)

DFD PROCESS	DFD	RULE-BASED (Y/N)	RELATED DFD	TYPE OF SYSTEM
WAR GAME	7.5			
G2/IPB		Y	2.0,3.0,6.0,7.1	DM
Synch Matrix		Y	4.1,5.0,6.0, 7.4,9.0	Synch
Critical Events		Y	4.0,4.7,6.0,7.4	DM
DETERMINE BEST COA	7.6	N		
DECISION	8.0			
Mission		Y	1.0,6.0,6.2,9.0	Norm
CDR's Intent		Y	1.0,4.0,5.0, 6.3,7.4,9.0	Norm
Warning Order		Y	4.7,5.0,8.0	Norm
PREPARE PLANS AND ORDERS	9.0			
Synch Matrix		Y	4.1,5.0,6.0, 7.4,7.5	Synch
Mission		Y	1.0,6.0,6.2, 8.0,9.0	Norm
CDR's Intent		Y	1.0,4.0,5.0, 6.3,7.4,8.0	Norm
CDR's Guidance		Y	1.0,6.2	Norm
Task Org		Y	4.6,6.0,6.3,7.3	DM
Critical Events		Y	4.0,4.7,6.0, 7.4,7.5	DM
FRAGO/OPORD		Y		PO

TABLE 2 (Continued).

CHAPTER 6 END NOTES

[1]US Army, ST 100-9, The Command Estimate, (1989): 1-4.

[2]ST 100-9 (1989): 2-1.

[3]Ibid: 2-7.

[4]ST 100-9 (1989): 2-1.

[5]Ibid: 7-1.

[6]US Army, FM 101-5, Staff Organization and Operation (1984): E-20.

[7]ST 100-9 (1989): 2-3.

[8]Ibid: 2-6.

[9]Ibid: 2-7.

[10]Ibid: 2-8.

[11]Rand, "Understanding Commanders' Information Needs." (1989): 15.

[12]ST 100-9 (1989): 3-1

[13]Ibid (1989): 3-2.

[14]Ibid (1989): 3-1.

[15]Ibid (1989): 3-4.

[16]Ibid (1989): 3-5.

[17]Ibid (1989): 3-6.

[18]Interview, LTC John A. Strand, 6 Feb 1990, Future Battle Lab, Fort Leavenworth, KS.

[19]US Army, FM 100-5, Operations (1986): 34.

[20]ST 100-9 (1989): 3-7.

[21]Ibid (1989): 4-1.

[22]*Ibid* (1989): 4-1.

[23]*Ibid* (1989): 5-2.

[24]*Ibid* (1989): 5-2.

[25]*Ibid* (1989): 1-4.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

The command estimate is depicted as a cleanly defined flow diagram in ST 100-9, The Command Estimate[1]. This diagram shows discrete processes that isolate and perform specific functions in a linear manner. However, when the functional decomposition of this process is analyzed, the command estimate is more aptly described as a three dimensional tinker toy structure. Although specific functions are performed by discrete processes, the information flowing into and out of these processes is dynamically and simultaneously linked to other processes. The flow of this information is not linear, but, is instead, recursive.

In the tinker toy model analogy, the processes are the wooden spools while the information flows are the shafts. Data stores and sinks are represented by other shapes that are connected to various wooden spools by shafts. Multiple shafts connect the spools forming a complex polyhedron. This sophisticated structure is more representative of the command estimate during execution

where the amount and timeliness of information necessary to make decisions is nearly unmanageable when using current manual and automated systems.

It is important that the Army pursue advanced technology to improve the command estimate. Automation must be exploited to manage the vast amounts of information generated in tactical situations. In the civilian sector, executive information systems (EIS) have been implemented to allow executive decision makers to access a broad spectrum of data, perform rapid analysis which produces intelligent information, and then make informed decisions. The introduction of rule-based expert systems within EIS allows executives to make decisions with the best current information while avoiding the common fault of providing too much detailed information. These same capabilities have a demand in the military environment.

CONCLUSIONS

The use of rule-based systems has a viable function within the command estimate. As described in this study, the command estimate is a series of interrelated sub-systems. The creation of a rule-based environment for the command estimate should follow a

modular architecture and be comprised of rule-based subsystems that assist the commander and staff in the execution of the command estimate.

Development of rule-based systems to assist in the performance of the command estimate should accomplish the following functions:

1. Normalization.
2. Synchronization.
3. Data maintenance.
4. Consultancy.
5. Computation.
6. Preparation and dissemination of orders and graphics.

Normalization is the process of parsing an expression or statement into its component words and phrases and making them adhere to an established vocabulary. This ensures that the expressions will have a precise and understood meaning. In the command estimate context, statements must conform to terms in FM 101-5-1.[2] This normalization to the standard terminology will ensure that a statement will mean exactly what it says. An example is the nuances between the phrases, "Secure the objective." and, "Seize the objective." FM 101-5-1 defines secure as:

> To gain possession of a position or terrain feature, with or without force, and to deploy in a manner which prevents its destruction or loss to enemy action.[3]

Seize is defined as:[4] "To clear a designated area and obtain control of it."

The fine line between the two being that in a secure mission, forces do not have to establish a physical presence on the the position or terrain. In the seize mission, forces have to occupy the designated area. This distinction is minor but can have a tremendous effect on the unit that has to accomplish the mission. Unfortunately, these two terms are often used interchangeably by military planners and operators. The common military vernacular is rife with such terms that have similar, but vastly different meanings. A rule-based system that normalizes statements either being received or being transmitted will ensure unity of meaning.

The process of normalization is also applicable to diagrams, sketches, and other pictorial representations of military operations. It is just as important that these graphic expressions conform to correct doctrine as written media. More important, if a sketch is used to complement a written communication, it must convey the same information as the written media. A rule-based system for normalization can accomplish this.

In military operations, timing is everything. The synchronization of combat, combat support, and combat service support resources at the critical place and time is necessary for success. A rule-based system can excel

at the process of assisting in the synchronization and employment of battlefield operating systems (BOS) due to the ability to track and analyze multiple variables. If, in a course of action, the time for some event is adjusted for some reason, all other synchronization times can be adjusted automatically. In addition to time synchronization, a rule-based system can assist in the coordination of resources at critical locations. An example is a river crossing where a wide variety of specialized engineer equipment is necessary to construct, then maintain a bridge. The rule-based system could assist commanders and staffs by producing a detailed synchronization matrix of the necessary assets and actions keyed to specific times or other events. The result is a tool to better and more efficiently manage time.

Data maintenance is a method of tracking statuses of units, personnel, equipment, etc. After a specific entity or item of information is captured, it can be continually monitored for changes. Several methods could be used to trigger this function to include time periods, exception criteria, or demand polling.

Time period data maintenance is a case in which the status of the item is reported at set periods of time. Exception criteria is when the item exceeds specified tolerances. Demand polling is when the status of the item is requested.

Much time and effort of commanders and staffs is spent in maintaining time sensitive data. Often, current information is the basis for critical decisions. A rule-based system can assist in maintaining the most reliable, timely, and correct data. Better decisions are made if the information on which they are made is maintained to a higher quality.

Consultancy is an area where the rule-based system can act as the commander's personal consultant on matters of doctrine or military science. It is here that checks can be made to ensure that all of the battlefield operating systems have been addressed in a particular course of action or that the doctrinal tenets of AirLand Battle have been included in the plan. The rule-based system can ensure that the staff estimate is complete and addresses all necessary aspects.

Several areas of the command estimate could be assisted with automated resources to provide computational power. These include forecasting logistical requirements, air and road movement tables, ammunition expenditures, personnel projections, etc. A rule-based system to perform computational routines could determine when to recalculate existing data based on changing parameters of the tactical situation as a whole. Assisting this type of process with rule-based expert systems will consistently result in more accurate results.

Preparing output is necessary for the production of the warning order, OPORD, and FRAGO. This is a fairly straightforward application of a rule-based system that places information into a prescribed format such as a five paragraph operations order and then distributes it to a list of addressees. In addition to creating the OPORD or FRAGO, a rule-based system can also determine which addressees get the output. A final feature of a rule-based output system is that it can verify whether or not all intended recipients actually receive the information. If the information is not received, the rule-based system can try alternate communication means to deliver the information and keep the commander and staff informed of the status.

RECOMMENDATIONS

The analysis of examining the command estimate from aspects of both formal observations and a systems analysis method of functional decomposition has revealed many areas that can be assisted by the implementation of rule-based systems. From the general level, each defined process of the command estimate is a candidate for a rule-based system to act as a consultant to ensure congruency to doctrine or procedure. However, underlying these rule-based consultant systems would be specific rule-based systems that focus on more specialized areas or

procedures. This "system" of rule-based expert systems would capitalize on modern technology to give the commander and staff a more powerful and accurate command estimate.

Table 3 enumerates the types of rule-based systems that can be developed for each sub-system of the command estimate. This table divides the command estimate into its traditional sub-systems and generalizes the rule-based expert system scheme required to assist the commander and staff.

RECOMMENDED RULE-BASED SYSTEMS

COMMAND ESTIMATE PROCESS	TYPE OF RULE-BASED SYSTEM
Mission	Consultant Normalize Mission Statement Data Maintenance
Facts and Assumptions	Consultant Data Maintenance Computation
Mission Analysis	Consultant Synchronize BOS Normalize Mission Statement Prepare Warning Order
Commander's Guidance	Consultant Normalize CDR's Guidance Prepare Warning Order
Develop Courses of Action	Consultant Synchronize BOS Prepare COA Statement
Commander and Staff Input	Consultant Synchronize BOS
Analyze Courses of Action	Consultant Synchronize BOS War Game Simulation
Recommendation	Consultant Synchornize
Decision	
Warning Order OPORD/FRAGO	Consultant Normalize Orders and Graphics Prepare Orders and Graphics

TABLE 3.

PRIORITY OF RULE-BASED SYSTEM IMPLEMENTATION

The functional decomposition of the command estimate and the IPB identified key elements that either occurred numerous times or had a significant impact in more than one sub-system. Additionally, the examination of observations made of the command estimate in action revealed several areas that are candidates for enhancement with automated systems. The analysis and comparison using these methods provided complementary findings that rule-based expert systems could make a significant contribution in the execution of the command estimate. The order of priority in which rule-based expert systems should be implemented within the command estimate is:

1. Commander's intent.
2. Time line and synchronization matrix.
3. Mission statements.
4. G2/S2 IPB.
5. Task organization.
6. Critical events.
7. Warning orders.

COMMANDER'S INTENT

The commander's intent is the single most often recurring entity of information within the command estimate. This intent is the commander's mental image of

the battlefield; it drives the entire planning and execution process. The staff that understands what the commander envisions on the battlefield will have a greater chance of creating an integrated plan to accomplish the mission. This process is well suited for enhancement by rule-based expert systems. The focus of this effort would be to normalize the verbal and graphic expression to doctrinally correct terms and graphics.

SYNCHRONIZATION

The time line or synchronization matrix is the second most often occurring item of information. This is in line with the commander's intent because to achieve the mission, the resources of the battlefield must be synchronized in time and space to bring critical forces to bear on the enemy. This is an ideal area for the implementation of rule-based systems to assist the commander and staff in identifying critical times and managing the synchronization of combat resources. This system would assist in the synchronization of battlefield operating systems (BOS) in time and space to bring all critical resources to action when and where they are needed. It would also act as a consultant for the various systems to ensure that all resources are addressed and planned for to leverage their capabilities.

MISSION STATEMENTS

Normalizing the mission is a prime candidate for assistance with a rule-based system. Although very similar to the commander's intent, it is distinct and separate. The purpose of a rule-based system to assist in mission statements is normalization and dissemination to appropriate addressees. It would also ensure that overlay graphics are consistent in military verbiage and display doctrinally correct symbols.

G2/S2 IPB

The IPB is not depicted by <u>ST 100-9</u> as a primary component of the command estimate. However, it is inconceivable that any tactical operation could be conducted without a thorough IPB. Therefore, it is recommended that the IPB be included in any rule-based assistance focused on the command estimate. In this light, the IPB is a process that rule-based systems can perform with relative ease due to the modularity of its functions and the nature of the information that flows into and out of the process. The primary focus of rule-based systems for the IPB will be that of consultancy. This is due to the complex knowledge of enemy equipment and doctrine required as well as a depth of knowledge of friendly force structures and capabilities. Rule-based sub-systems can perform computational processes such as force ratio calculations, weather forecasting, and terrain

analysis. Data maintenance functions can be designed to track and maintain data bases such as enemy order of battle, alerting the staff in the case of information concerning certain types of equipment or activities are processed, and trend analysis of current situations.

TASK ORGANIZATION

The development and tracking of task organizations is a rule-based task that would contribute much to the commander's planning process. Data maintenance is an obvious role of such a system. In addition to tracking the units allocated for an operation, the current status of these units in a wide range of specified areas could be maintained. The commander would automatically be alerted if the sensitivity levels of pre-set thresholds were violated. This feature would provide a measurable improvement over the present method of maintaining current statistics on units. A consultant rule-based system can perform the task of assisting the commander and staff with employing allocated forces within doctrinal parameters. This would overcome training shortfalls in cases where non-standard units are allocated as resources such as an Army division receiving control of a Marine Corps force. The consultant would draw upon doctrinal rules to assist the commander in employing these non-standard resources to the maximum benefit.

CRITICAL EVENTS

Critical events are either the essential tasks or the key actions that influence what occurs on the battlefield. A rule-based system would perform data maintenance and insure that information concerning these events is properly disseminated. Working in concert with other expert systems, it would overwatch the process of synchronizing BOS with anticipated or critical enemy actions.

WARNING ORDERS

The preparation of orders is one area that rule-based expert systems will noticeably save effort and reduce confusion. Much of the information contained in formatted orders is a recapitulation of information on hand. The process of updating this and including it in both formal and informal formats takes time and presents opportunities for conveying erroneous information. A rule-based expert system assisting the command estimate process will reduce the time it takes to prepare and issue orders and can track missing items of information for later filing. This system will also control the distribution of the orders.

ATCCS AND RULE-BASED EXPERT SYSTEMS

The implementation of rule-based systems within the command estimate should proceed in increments as in the above sequence. The hardware platforms that are being

fielded to support ATCCS can be used to operate rule-based systems. This implementation effort should be incremental and coordinated in that the each sub-systems be pr... individually before it is integrated with other sub-systems.

The measure of success of rule-based systems is that they assist in the execution of the command estimate, not interfere or be an impediment with any other ATCCS system, and be totally transparent to the user in the field. The main concern is that the rule-based expert systems are to assist the commander and staff in the execution of the command estimate, not replace them.

The evolving ATCCS is the environment on which to develop rule-based expert systems for the command estimate process.

CHAPTER 7 END NOTES

[1]US Army, ST 100-9, The Command Estimate, (1989): 1-4.

[2]US Army, FM 101-5-1, Operational Terms and Symbols (1985).

[3]Ibid (1985): 1-64.

[4]Ibid (1985): 1-65.

APPENDIX A

APPENDIX A

ANALYTICAL DECOMPOSITION OF THE INTELLIGENCE PREPARATION OF THE BATTLEFIELD (IPB)

The intelligence preparation of the battlefield (IPB) is the methodology used by the G2/S2 to analyze the enemy, terrain, and weather in a specific geographical area. The IPB integrates known enemy doctrine with the nonstandard conditions of weather, terrain, the mission, and the specific battlefield area. The product of this process is an intelligence estimate and an analysis of the battlefield area that will indicate probable enemy courses of action and intentions.[1]

Figure 13 depicts the IPB. It is a cyclical five-function process that has the following components:

1. Battlefield area evaluation.
2. Terrain analysis.
3. Weather analysis.
4. Threat evaluation.
5. Threat integration.

The IPB is closely associated with the command estimate but is not an integral component. While the command estimate represents the military decision making

THE IPB PROCESS

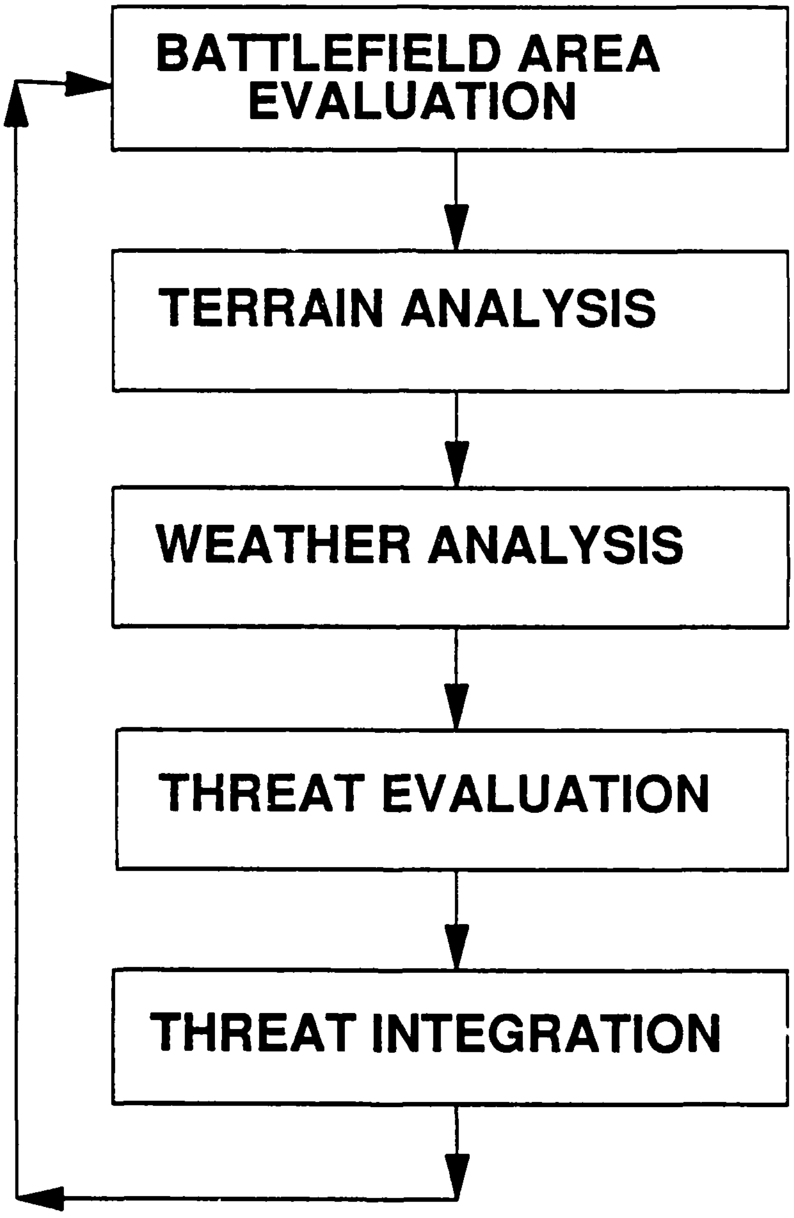

Figure 13.

model and can be used in any situation, the IPB is a G2/S2 function that focuses on a known enemy military force, a specific geographic area, and the effects of terrain on military capabilities.

The purpose of this appendix is to examine the IPB with respect to how it functions with the command estimate and to determine if it should be assisted with rule-based expert systems.

BATTLEFIELD AREA EVALUATION (BAE)

While the IPB is a continuous process, the interface to the command estimate is the process of mission planning. The trigger for the IPB is the mission. The mission establishes the WHO, WHAT, WHERE, WHEN, and WHY. Figure 14, BAE Data Flow Diagram (DFD) depicts the information that flows into the BAE process and what it becomes as the result of the evaluation.

The mission statement was displayed as an output of the command estimate in DFD 1.0, figure 4. Additionally, several data stores from the command estimate help to shape the process of determining the area of operations. These inputs are the commander's guidance (DFD 1.0, figure 4), the geographic WHERE (DFD 1.0), facts (DFD 2.0, figure 5), and assumptions (DFD 3.0, figure 5). These data stores are generated or maintained by the G3/S3.

IPB BATTLEFIELD AREA EVALUATION

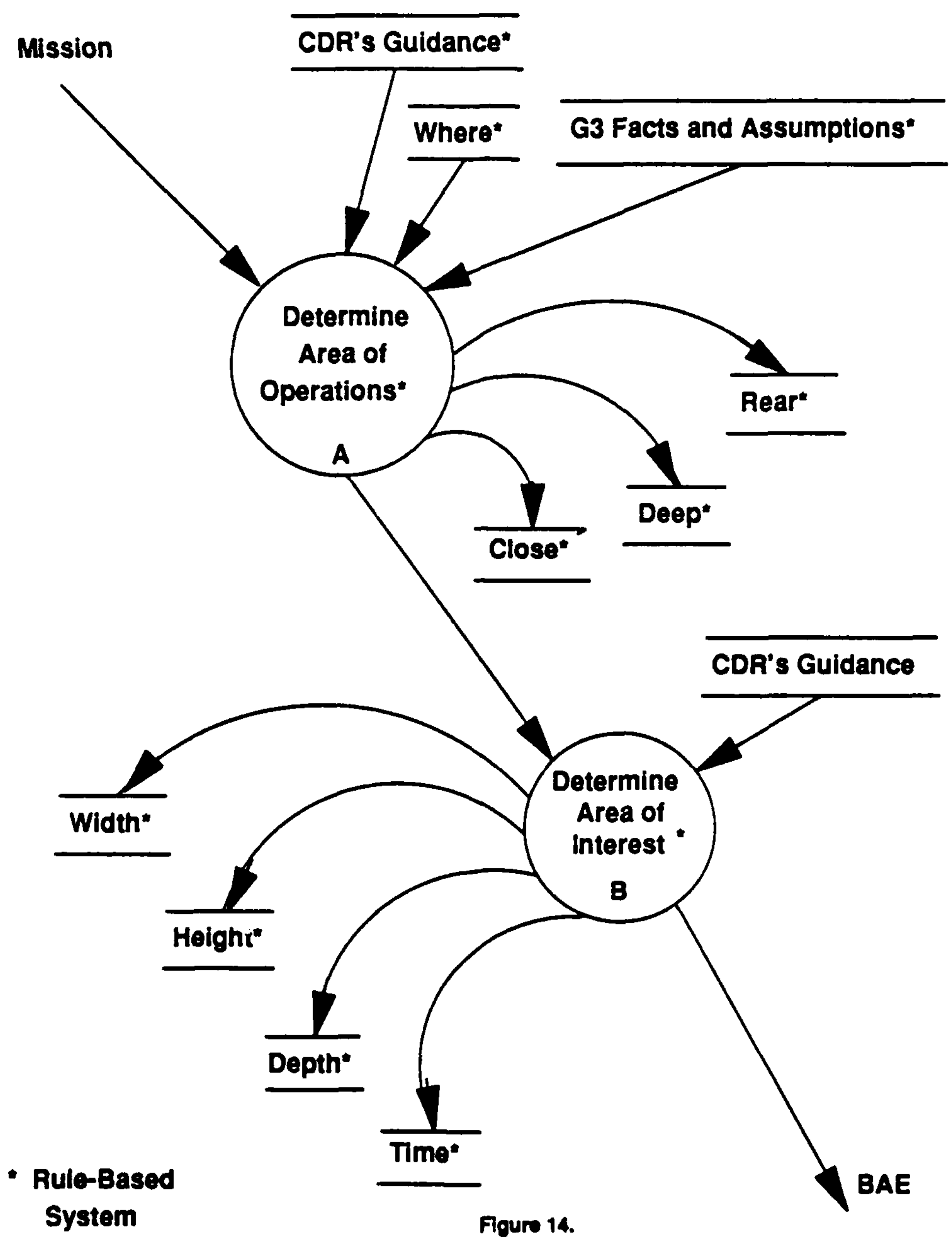

Figure 14.

The first process is to determine the area of operations. The area of operations is roughly defined by the G3/S3 and is the specific zone or area the commander is responsible for.[2] DFD A in figure 14, shows this determination is stored as the definition of the close, deep, and rear areas. Although the operations in these areas will be conducted simultaneously, the IPB is conducted in each process in a slightly different manner.[3] Hence, each is stored as a separate entity that becomes a subset of the WHERE in the mission data store.

The second process of the BAE is to determine the area of interest. This area is jointly determined by the G2/S2 and the G3/S3 based largely on the commander's guidance. This is a larger area that includes enemy activity which might effect friendly forces during the operation.[4] The boundaries of this area must be synthesized from a knowledge of enemy capabilities, friendly vulnerabilities, and the military aspects of terrain. DFD B, figure 14, depicts this process. Outputs are data stores that contain the dimensions of width, height, depth, and time that delimit the area of interest. Like the battlefield parameters generated in DFD A, the dimensions of width, height, depth, and time become refined subsets of the mission data store.

The role for rule-based expert systems in this process is two-fold. First, all the information inputs

have been recommended for assistance using rule-based systems. Although these inputs are initially generated in the command estimate as shown in DFDs 1.0, 2.0, or 3.0, they are continuously updated as information changes. A rule-based system would excel at the data maintenance task to insure decisions made based on the IPB are correct with respect to timely and correct information. Second, the process of performing the BAE is a candidate for assistance by a rule-based system using the inputs of mission, capabilities of enemy forces, vulnerabilities of friendly forces, and the commander's guidance. The BAE process is continuous. A rule-based expert system in a consultant role would update this evaluation as the situation changed.

TERRAIN ANALYSIS

Understanding the limitations and opportunities of terrain is a fundamental military skill that varies among levels of command. Terrain is analyzed at each echelon. However, regardless of what echelon is involved, the unit's mission is the primary concern of the analysis. The depth, or fidelity, of the process is driven by the echelon of the staff performing the analysis. Lower tactical echelons conduct a much greater examination of a small area taking into consideration the

military aspects of terrain. At the operational level, additional factors are considered such as population density, transportation facilities, and physical resources.[5]

The initial process in terrain analysis is the identification of gaps in terrain data. Figure 15 depicts the decomposition of this terrain analysis process. The mission provides the WHERE for the operation. This is the same data store that was generated in the mission process of the command estimate (DFD 1.0, figure 4), and appears multiple times during later phases. In the IPB, it is a refined WHERE of DFD A. This item of information specifies requirements for maps, intelligence efforts, terrain studies, and detailed reconnaissance. A data store of facts can provide some of this data. This is the data store that was initially generated in DFD 2.0, figure 5. The items that are not identified as being available create a data store for gaps in the terrain data. This data store is a refinement to the facts data store.

It would be the function of a rule-based system to identify the information requirements from the mission statement, determine what information is available, determine what information is needed, and take steps to acquire the missing information. An example would be that the rule-based system would receive the mission statement and determine what maps are needed for the

TERRAIN ANALYSIS

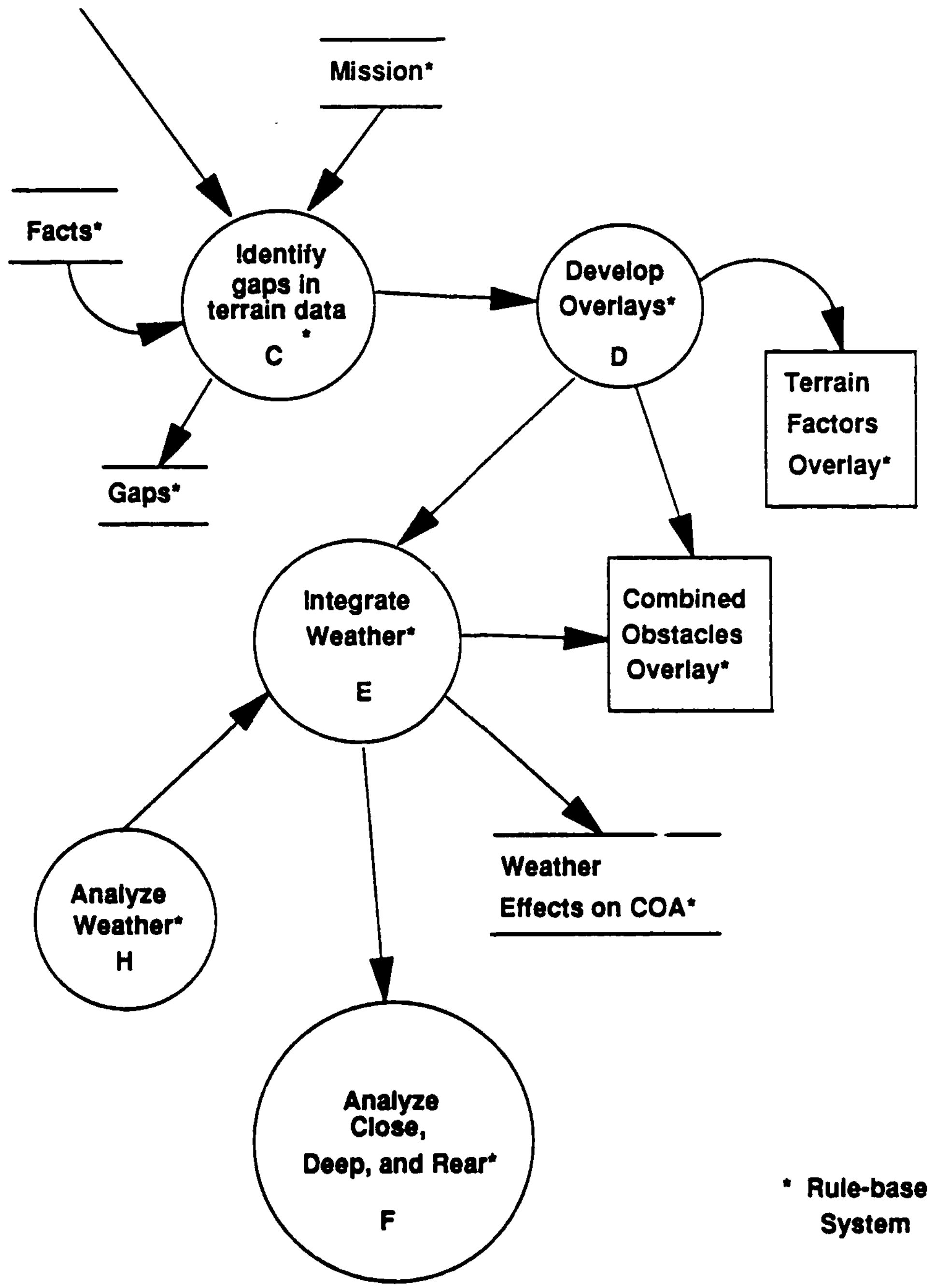

Figure 15.

operation. It would then check the data store of facts for map status. In case the maps were not available, it would requisition them, or initiate map production from computer maintained digitized terrain data. In any event, it would alert the appropriate staff sections that a potential problem exists and what steps have been taken to correct it.

The next process is the development of overlays to graphically depict relevant factors of the area. These overlays can be created to portray any type of information based on availability of information and the desire of the commander and staff. This process is labeled DFD D. It has two primary overlays as outputs:

1. Terrain factors which reflect important military factors of specific battlefield areas. The analysis of the deep area may focus on transportation facilities, the examination of the close area may look at vegetation and streams, the areas of concern in the deep area may be possible airborne or air assault zones.

2. The combined obstacle overlay which depicts obstacles to movement. This is typified as go (favorable), slow-go (marginal), and no-go (unfavorable) terrain.

These overlays give the commander and staff a graphic picture of where forces are expected to operate on the battlefield. The primary source of the base-line

data for this analysis is standard topographic data provided by the Defense Mapping Agency.

Although man is much better at pattern recognition tasks such as map-based terrain analysis than current artificial intelligence technology, this process could be greatly assisted with rule-based systems.[6] The use of digitized terrain data instead of standard topographic maps would leverage the ability of a computer-based system to perform this task. A rule-based system could normalize graphics to doctrinal standards and supervise its dissemination to appropriate agencies.

The analysis of terrain and weather are separate steps but are done concurrently.[7] DFD E, figure 15, is the process of integrating weather into the analysis of terrain. This is a recursive procedure that must get information from the process of analyzing the weather performed in DFD H.[8] The integration of weather generates two outputs with the first being an enhancement to the combined obstacle overlay produced in DFD D, and the second being a data store containing a summary of the effects that weather may have on courses of action.

The integration of weather is a superb candidate for assistance with rule-based systems. Essentially, this process is largely a data management function that takes information provided by sensors and applies it to specific geographical areas. The data store is then

TERRAIN ANALYSIS
(Continued)

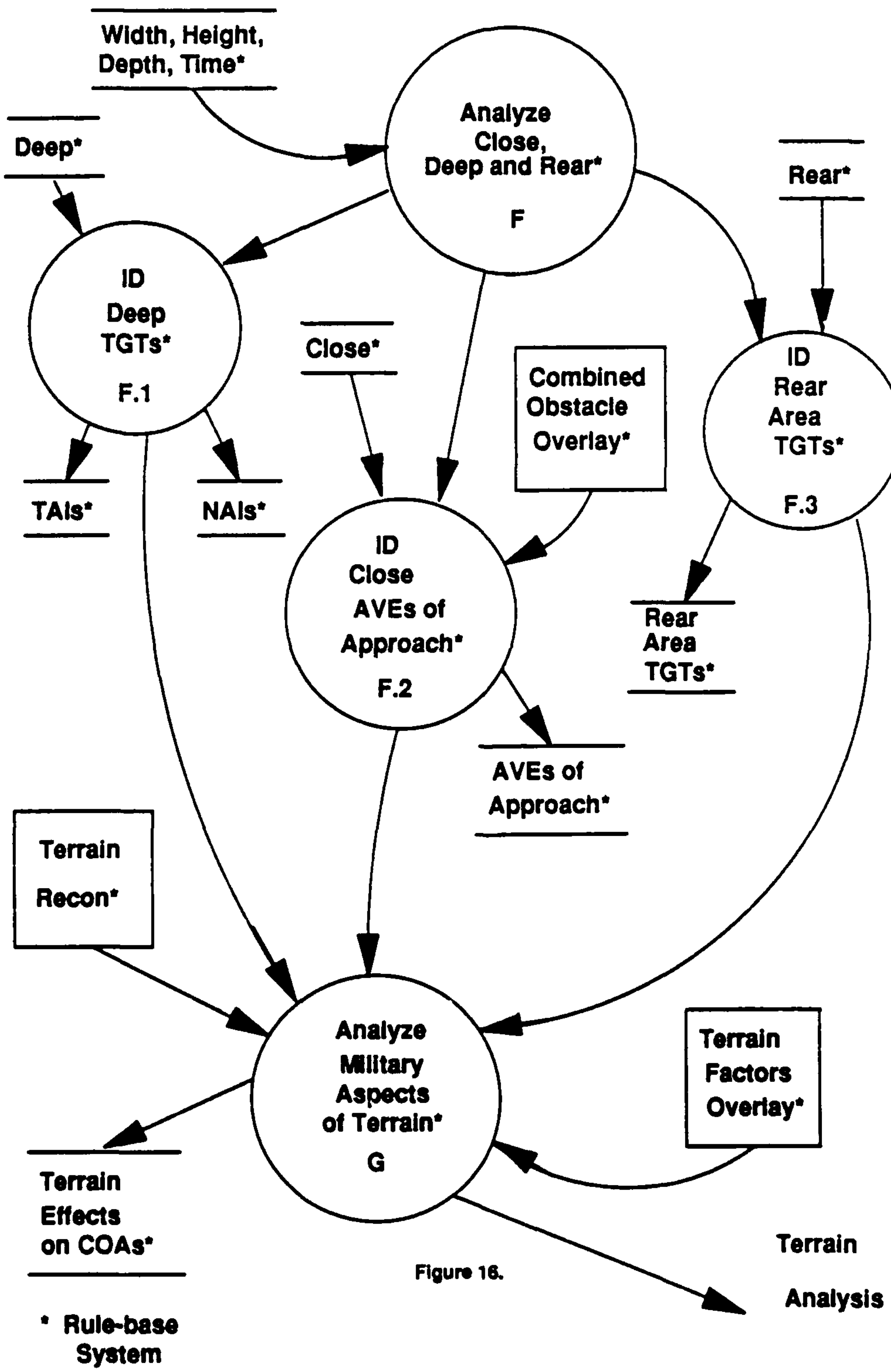

Figure 16.

maintained for specific operations in areas on which the weather will have an measurable effect.

The analysis of the close, deep, and rear areas is a convoluted procedure. DFD F in figures 15 and 16 depicts the starting point for this process. The data stores of the battlefield parameters of width, height, depth, and time developed in DFD B are inputs into this transformation. Figure 16 details three parallel transformations:

1. Identification of deep targets for intelligence collection and interdiction. This transformation is given the input of the deep area data store as it was defined in DFD A. These targets are identified as terrain features such as bridges, mountain passes, forested areas, etc. Initially, these are designated named areas of interest (NAI) and will be designated as targeted areas of interest (TAI) as threat forces are integrated into the analysis. These produce two data stores called NAI and TAI. Avenues of approach in the deep area are primary candidates for designation as NAIs and TAIs.

2. Identification of avenues of approach (DFD F.2) for close operations. The close area was defined in DFD A, figure 14. The combined obstacle overlay produced in DFD D, figure 15, defines areas through which forces can move. Avenues of approach can be identified using

rules developed from doctrinal attack frontages. The use of these rules results in identification of both friendly and enemy avenues of approach.[9] These avenues create a data store that will be used in developing and analyzing courses of action in the command estimate.

3. Identification of targets in the rear area of operations (DFD F.3). The rear area was designated in DFD A, figure 14. The targets in the friendly rear area provide insight into options available to the enemy. The output of this process is a data store of rear area targets. This will be used with the process of threat evaluation to form the basis of the intelligence estimate.

The analysis of close, deep, and rear areas is a candidate for rule-based systems. A caveat is that machine readable terrain data must be available. The process of identification of avenues of approach is a prime example of using doctrinal rules to assist the military decision-making process.

Analyzing the military aspects of terrain is the final element in the terrain analysis process. DFD G, figure 16, depicts this procedure. This is done from both a friendly and enemy perspective to determine merits and problems. Primary inputs are the terrain factors overlay and any information gleaned from a terrain reconnaissance. Additional information such as aerial imagery may be used. The primary output is a data store

that contains information on the terrain effects on avenues of approach for the various courses of action.

This analysis process can be greatly assisted with a rule-based expert system. Military aspects of terrain can be evaluated with a quantified set of rules. The information from the terrain factors overlays can be processed by the rule-based system. Additionally, information from any terrain reconnaissance or surveillance data can be processed by the rule-based system.

WEATHER ANALYSIS

Weather analysis is the process to determine the effects of weather on both enemy and friendly courses of action. Of concern are those weather effects that will act as limitations or enhancements on personnel, equipment, or the military operation. Figure 17 depicts this process which is initiated by the inflow of information defining the battlefield. These are the BAE products created in DFDs A and B, figure 14, which delimit the area of operation and the area of interest. The mission is a data store that defines the WHAT and the WHEN of the operation. A large data store of facts will provide two large categories of weather information:[10]

1. Traditional weather products such as climatology studies, light-data, average temperatures, average precipitation, seasonal cloud cover, etc.

WEATHER ANALYSIS

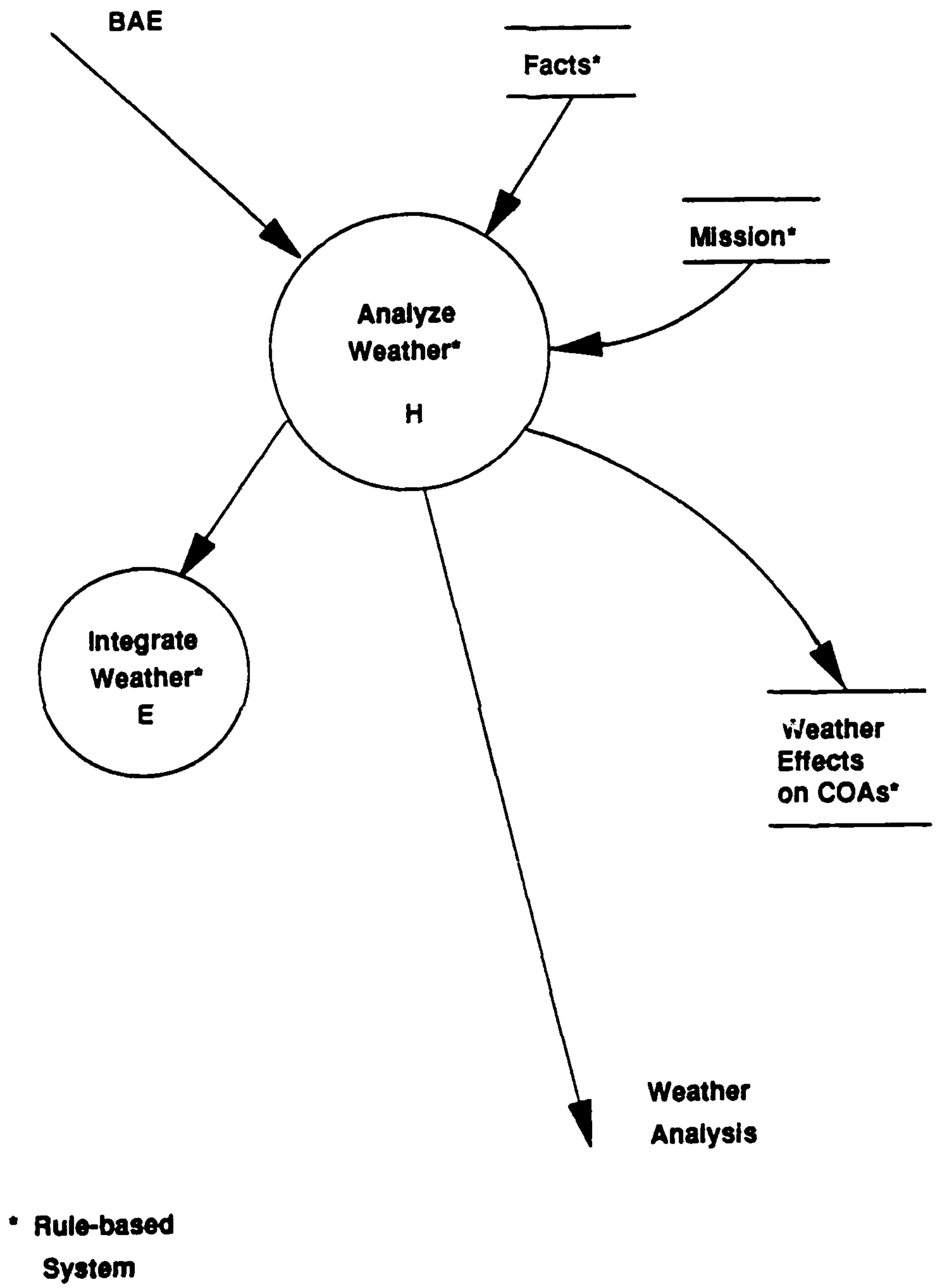

Figure 17.

2. Weather studies and forecasts on likely seasonal conditions as they will effect various courses of action.

These inputs are transformed by the analysis process and produce a data store of the effects of weather on the courses of action, and overlays of weather effects. The overlays may depict significant effects to include fog, cloud cover, rain, snow depth, ice thickness, wind direction, wind speed, and any other factor that may have a measurable effect on the military operation.[11] Another output is the process of integrating weather into the terrain analysis. This was depicted as DFD E in figure 15.

The entire process of weather analysis is a candidate for assistance with rule-based systems. The inputs have been previously recommended for rule-based systems. The actual process of analyzing the weather is the use of scientific meteorological rules on current data and historical records. The outputs are a data store and the production and dissemination of overlays. Both of these outputs can be managed by an automated system. A rule-based system is well suited for normalizing overlay graphics to doctrinal standards and assisting in the dissemination of the product.

THREAT EVALUATION

Threat evaluation is the detailed examination of the enemy forces, composition, weapons, equipment, organization, and supporting battlefield functional systems. This process is to determine the enemy capabilities and how they operate as prescribed by their doctrine.[12] The mission drives the threat evaluation process. It defines the basic environment that the forces must operate in. DFD I in figure 18 details this process.

The primary inputs into the threat evaluation process are facts, assumptions, rear area targets, and avenues of approach. Facts and assumptions are data stores that were generated in DFDs 2.0 and 3.0 in figure 5 of the command estimate. These data stores are related. Assumptions are used in lieu of unknown facts. Once facts become known, they replace these assumptions. The data stores of rear area targets and avenues of approach were generated in the terrain analysis process, DFDs F.2 and F.3, figure 16.

Facts often include information on enemy disposition, known locations, composition, strength, committed forces, and reserves. [13]

Assumptions are made of information that is missing or incomplete.

THREAT EVALUATION

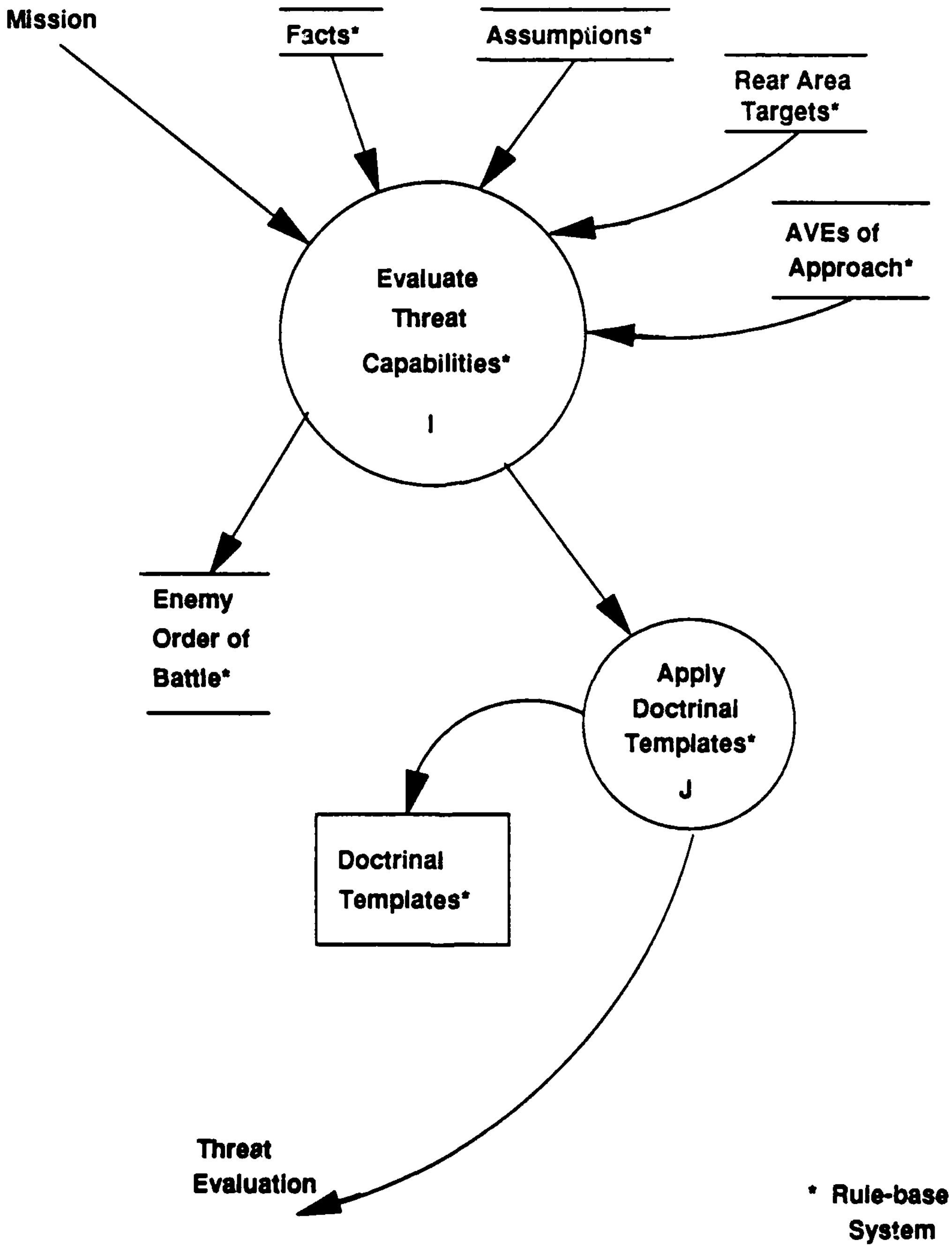

Figure 18.

The use of rule-based systems in support of the mission statement and management of data stores containing facts and assumptions have been discussed in detail. The bulk of this effort would be normalization of the mission statement to doctrinal terms, data maintenance, dissemination of facts and assumptions, and assistance in harvesting factual information from reports and messages. The data stores of rear area targets and avenues of approach will be dynamic and could be assisted by a rule-based system performing data maintenance.

An output of this process is a data store containing the enemy order of battle. This will be used extensively by the G2/S2 to make assessments of enemy capabilities and intentions. This data store can be maintained and disseminated by a rule-based system. Part of the maintenance function would be to filter incoming information to track units identified on the order of battle.

The next process is to apply doctrinal templates. These templates will produce graphic illustrations or overlays of enemy force structures, deployments, and capabilities that provide the commander a clear picture of the reality of the battlefield. These templates will provide the G3/S3 with notional enemy forces with which he can conduct the war game effort. This process is depicted in DFD J, figure 18. Doctrinal templates

convert enemy order of battle information into a graphic overlay presentation. These are models of how the enemy should look according to his doctrine and training if weather, terrain, and combat losses were not considered. The ultimate purpose of these templates is to provide a basis for integrating enemy doctrine with terrain and weather information. It is important that these overlays adhere to correct use of symbols to insure that the information conveyed is understood by all.[14]

The role of a rule-based system in the threat evaluation process would be to take rules of enemy war fighting doctrine and array the enemy forces from the order of battle as they would notionally be arrayed for combat operations. Doctrinal norms would be the source of the rule-base.

THREAT INTEGRATION

The climax of the IPB is the process of integrating enemy doctrine with terrain and weather data. The objective of this process is to determine how terrain and weather will effect how the enemy may fight. Threat integration is composed of several sequential steps in which templates are produced as outputs to assist in assessing how the enemy may act. These outputs will include the situation, event, and decision support templates.[15]

Figure 19 represents the sub-processes that generate the total process of threat integration. DFD K is the first transformation of information. Inputs are the threat evaluation, to include the doctrinal overlay, and the data stores of weather and terrain effects from DFDs E, figure 15, and G, figure 16. This information is transformed into how the enemy will make adjustments to established doctrinal dispositions, frontages, depths, and echelon spacing to account for the effects of terrain, weather, and combat losses.[16] The outputs from this transformation are a data store of enemy adjustments and a formal output of a situational template overlay. All the inputs and outputs of this process are candidates for assistance with rule-based systems. The inputs are simple data stores where the information is maintained and updated. The data store of enemy adjustments is a target for data maintenance. The output of the situational template overlay is targeted for normalization of graphics to doctrinal standards and dissemination to planning elements.

DFD L in figure 19 is the process in which the event templates are developed. Event templates identify significant battlefield events and enemy actions that will indicate enemy courses of action. It is a projection tool of what will most likely occur if the enemy adopts a particular course of action. Any area on the battlefield identified as critical is output as a

THREAT INTEGRATION

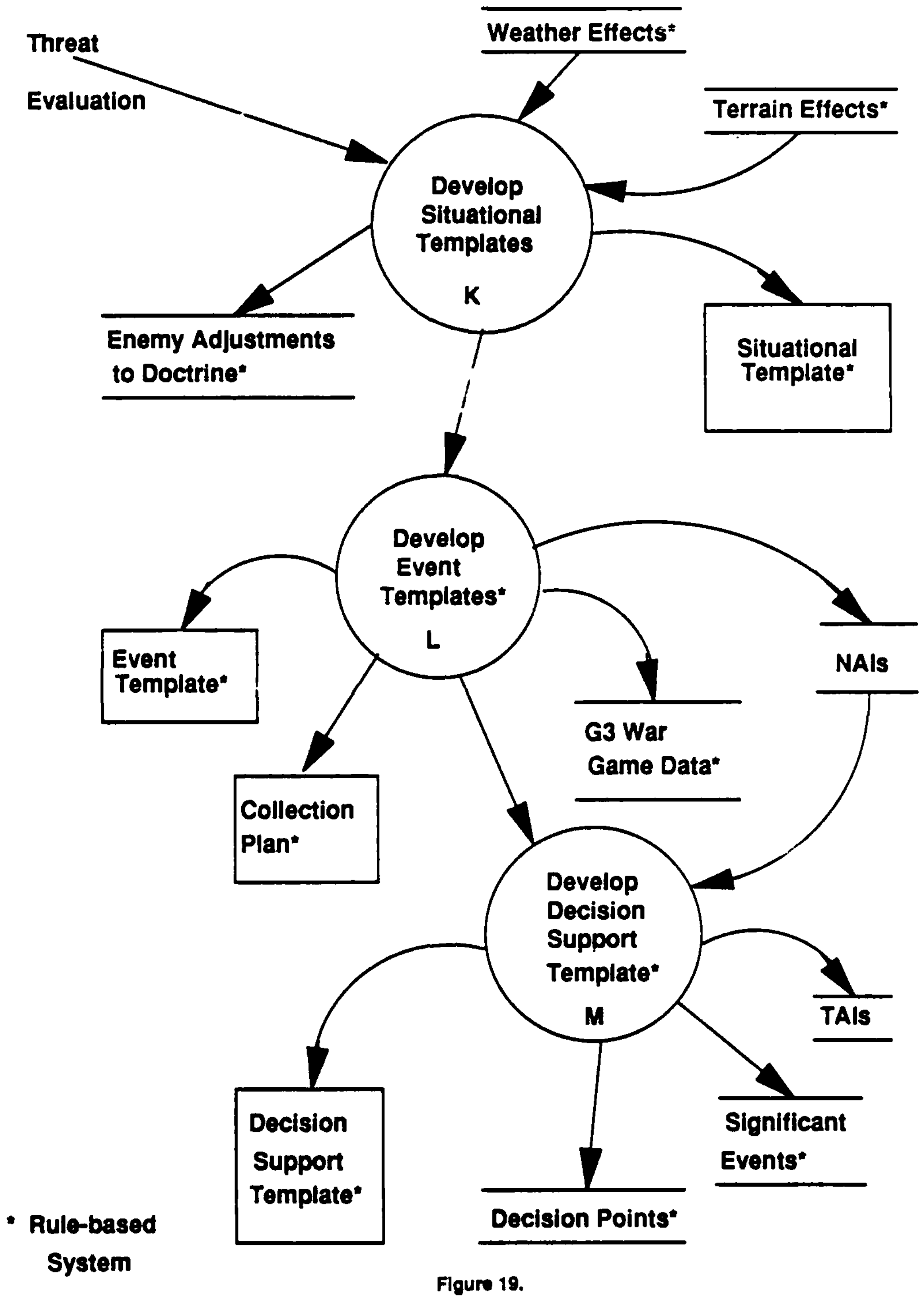

Figure 19.

data store labeled named areas of interest (NAI), which is a point or area where enemy activity or lack of activity will confirm or deny a particular enemy course of action.[17] This data store is also a data store input for DFD M, development of decision support templates. The event template itself is output as an overlay and is used in the war game process in DFD 7.5 of the command estimate, figure 10. Information that is germane to this template overlay is a data store output for the G3/S3 to conduct the war game. The G2/S2 uses the event template process to develop precise intelligence collection requirements. This is output as the collection plan and will be sent out as a part of the mission in the OPORD or FRAGO in the command estimate process.

DFD L can be greatly assisted with rule-based expert systems. Data maintenance, updating, and dissemination can be the tasks associated with the data stores of NAIs and G3/S3 war game data. Additionally, the data store of NAIs is used in the next process to develop decision support templates. Normalization, preparation of output, and dissemination would be the tasks for the rule-based systems assisting in creating event templates and collection plans.

The final process in threat integration is depicted as DFD M which is the development of decision support templates. This provides a guide to the

commander for when and where tactical decisions are required relative to battlefield events. This does not dictate decisions to the commander but identifies critical events and enemy activities that may require a decision. The primary input is the data store of NAIs that was generated in DFD K. An output is the target area of interest (TAI) data store. TAIs are points or areas where the commander can influence the action through fire and maneuver. Such action will cause the enemy to either abandon his course of action, or divert a tremendous amount of resources to continue with his mission. These are the areas where the enemy can be delayed, disrupted, destroyed, or otherwise manipulated.[18] A data store of significant events is generated that forms the basis of the determination of the decision points. The data store of decision points is another product of the threat evaluation process.

The decision points identify those battlefield events and areas that may require tactical decisions. These points also indicate the optimum time of when to make these decisions to retain freedom of action. The final product of the threat integration process is the output of the decision support template. This is an overlay that graphically depicts TAIs and decision points. This template will highlight the commander's opportunities and options and ensure timely and accurate decisions to allow retention of the initiative.[19]

DFD M, the process of developing decision support templates, is a candidate for assistance with rule-based systems. The inputs of the event template and NAIs are well suited for normalization and data maintenance, respectively. The data store outputs of TAIs, significant events, and decision points are targets for data maintenance and dissemination. The decision support template is the single most critical product of the IPB and should be assisted by a rule-based system to ensure that it is normalized to standard operational graphics and properly disseminated to planners and the G3/S3 for the conduct of the war game.

SUMMARY

The IPB is closely related to the command estimate but is a distinct and separate entity. It takes information from the command estimate, processes it, transforms it, and returns new information to the command estimate. Due to this symbiotic relationship, the same methodology used to decompose the command estimate and minutely examine information flow and processing was used on the IPB to identify those elements that can be enhanced by the use of rule-based expert systems. Table 4 encapsulates these findings and denotes those processes that would benefit from automated assistance.

ANNEX A SUMMARY

This table is a recapitulation of the information flows analyzed in the Intelligence Estimate of the Battlefield (IPB). The following key is used:
to explain the type of system indicated:
Norm Normalization of an expression or graphic to doctrinally correct form.
Synch Synchronization of action, equipment, or event to a common time reference.
DM Data Maintenance. Data is maintained in a store or data base. The information is constantly updated as changes occur.
Con Consultancy to ensure that doctrine and AirLand Battle tenets are adhered to.
CMP Computational procedures in which the rule-based system determines that a mathematical computation is necessary. It will continually update these computations as changes occur.
PO Prepare output of warning orders, OPORDs, FRAGOs, and related graphics.

DFD PROCESS	DFD	RELATED DFD	TYPE OF SYSTEM
BATTLEFIELD AREA EVALUATION	A		Con
Determine AO		6.0,7.1,7.3	Con
CDR's Guidance		1.0,6.2,9.0,B	Norm
Where(Mission)		1.0,6.0,6.2,8.0,9.0, C,H,I	Norm
G3 Facts		2.0,C,H,I	DM
G3 Assumptions		3.0,I	DM
Rear,Deep,Close		1.0,6.0,6.2,8.0,9.0, B,C,H,I	DM
Determine Area of Interest	B		
CDR's Guidance		1.0,6.2,9.0,A	Norm
Dimensions		See Mission	
TERRAIN ANALYSIS	C		Con
ID Gaps in data			Con
Mission		1.0,6.0,6.2,8.0,9.0, A,H,I	Norm
Facts		2.0,A,H,I	DM
Gaps		See Facts above	
DEVELOP OVERLAYS	D		Con
Terrain Factors		G	Norm
Combined Obs.		E,F.2,H	Norm

TABLE 4.

ANNEX A SUMMARY
(Continued)

DFD PROCESS	DFD	RELATED DFD	TYPE OF SYSTEM
INTEGRATE WEATHER	E		Com
Combined OBS.		D,F.2,H	Norm
Weather Effects			DM
ANALYZE CLOSE, DEEP, and REAR	F		Con
Dimensions		B	Con
ID DEEP TARGETS	F.1	G	Con
Deep Areas		A	Con,DM
NAIs		L,M	Con,DM
TAIs		M	Con,DM
ID CLOSE AVEs	F.2	G	Con
Close Area		A	Con,DM
Combined OBS Overlay		E	Con,DM Norm
ID REAR TARGETS	F.3	G	Con
Rear Areas		A	DM
Rear Area TGTs		I	DM
ANALYZE TERRAIN	G	F.1,F.2,F.3	Con
Terrain Factors overlay		D	Norm
Terrain Effects		K	Con
WEATHER ANALYSIS	H		Con
Facts		2.0,6.0,7.1,I	DM
Mission		1.0,6.0,6.2,8.0,9.0, A,C,I	Norm
Int Weather		E	Con
Weather Effects		K	Con
THREAT EVALUATION			Con
Capabilities	I		Con
Mission		1.0,6.0,6.2,8.0,9.0, A,C,H	Norm
Facts		2,0,6.0,7.1	DM
Assumptions		3.0,6.0,7.2	DM

TABLE 4 (Continued).

ANNEX A SUMMARY
(Continued)

DFD PROCESS	DFD	RELATED DFD	TYPE OF SYSTEM
THREAT EVALUATION	I		Con
Rear Area TGTS		F.3	DM
AVEs of Approach		F.2	DM
Enemy OB			DM
Apply Doctrinal	J		Con
Templates			Norm
THREAT INTEGRATION			Con
Dev Sit Tmplt	K		Con
Weather Effects		E	Con,DM
Terrain Effects		D	Con,DM
Enemy Adjustment		Refines G2/S2 data	DM
Situation Tmplt			Norm
Dev Event Tmplt	L		Con
Event Template			Norm
Collection Plan			Con,PO, Synch
G3/S3 War Game			DM
NAIs		F.1,M	Con,DM
Dev Decision	M		
Support Tmplt			Con
NAIs		F.1,L	Con,DM
TAIs		F.1	Con,DM
Sig Events		7.4,7.5,9.0	DM
Decision Points			DM
Decision Support Template			Norm

TABLE 4 (Continued).

The functional decomposition of the IPB provides one clear divergence from the command estimate: the commander's intent is not a consideration in the flow of information. This is due to the fact that the IPB is concerned with the area, the weather, the terrain, and the enemy. The commander's vision of the battlefield at the end of the operation is not, and should not be, part of this analytical process. However, the results of the IPB should be thoroughly integrated into the processes the commander uses to develop his intent, formulate his guidance, and generate the restated mission.

The intelligence preparation of the battlefield is an ideal candidate for assistance with rule-based expert systems. The primary reason for this is that the majority of the processes use clearly defined methods to produce results. These processes can be refined to a manageable rule-base on which an automated expert system can be created. The majority of the ancillary sub-processes are either to normalize template and overlay information to doctrinally correct symbology or to supervise the dissemination of information outputs to staff planners within adjacent or lower echelon organizations. The use of expert-systems in this environment will harvest measurable results.

APPENDIX A END NOTES

[1]US Army, ST 100-9, The Command Estimate (1989): 7-1.

[2]US Army, FM 100-5, Operations (1986): 35.

[3]ST 100-9 (1989): 7-2.

[4]FM 100-5 (1986): 35.

[5]ST 100-9 (1989): 7-4.

[6]Michael C. Albano and Robert A. Gearheart, JR., "An Initial Study Examining the Feasibility of Expert System Technology for Command and Control of Supporting Arms in the United States Marine Corps," Master Thesis, Naval Postgraduate School, (1988): 31.

[7]ST 100-9 (1989): 7-5.

[8]Ibid: 7-10.

[9]Ibid.

[10]Ibid: 7-22.

[11]Ibid.

[12]Ibid: 7-1.

[13]Ibid: 7-26.

[14]Ibid.

[15]Ibid: 7-1.

[16]Ibid: 7-27.

[17]Ibid: 7-32.

[18]Ibid: 7-36.

[19]Ibid.

APPENDIX B

APPENDIX B

INTERVIEWS

During the course of the research for this thesis, a number of interviews with functional area experts were conducted to gain knowledge of artificial intelligence, rule-based expert systems, and the workings of the command estimate. It was the initial intent to perform these interviews using electronic mail on the Defense Data Network. Unfortunately, the majority of the people who were interviewed either did not have access to E-mail or declined to use that medium for interviewing.

This appendix contains a synopsis of the interviews that were conducted.

CAPTAIN GARCIA, Center for Army Lessons Learned

CPT Tony Garcia is a command and control analyst with the Center for Army Lessons Learned (CALL) at Fort Leavenworth, KS. This interview was conducted on 12 January 1990.[1] The focus of the interview was his observations at the National Training Center (NTC) with respect to the tactical implementation of command and control in a realistic combat environment.

CPT Garcia stated that the biggest problem that units have in using the command estimate is

synchronization. The synchronization matrix is a recommended tool for the 71 series (mechanized infantry and armor) field manuals. In observations of units operating at the NTC, it is not used because it is just too complicated and takes up too much time. This is complicated by the fact that the staffs, as seen at NTC, are often tired and deprived of sleep. The use of such tools requires a high degree of cognitive awareness that most of the staff officers lack after several days of continuous operations. This symptom extends to other tools available for use.

CPT Garcia was asked to comment on those areas that could possibly benefit from automation. He suggested that the S3 and S4 staffs could benefit most from automation enhancements and staff planning aids for generating march tables, forecasting logistics, or other projections using quantitative procedures.

CPT Garcia then stated that there are areas of the command estimate that could benefit from AI automation:

Mission Analysis: The biggest problem here is that commanders and staffs do not analyze and manage time well. What is needed is a tool that, when given a time line from initiation to mission accomplishment, can time manage critical tasks. This tool must be able to determine how long each sub-process of the command estimate should take, based on historical analysis of that

unit's performance, and suggest those steps that can be abbreviated, combined within other steps, modified, or completely ignored.

Commander's Guidance: Often, this is not articulated well to the staff. It is either unorganized or compounded by problems with basic terminology.

Course of Action (COA) Development: A recurring problem is that steps are continually being missed or conducted out of order.

COA Analysis: The war gaming phase is often not done well because the relative level of training within the staff. At task force level, the S2 is often a junior officer who does not have the experience to conduct adversarial war gaming well. What is needed is a docrinally correct threat adversary against which to war game courses of action. A desired product of this phase would be a synchronization matrix. Also, logistics, either friendly or enemy are not well orchestrated into the war gaming process. Currently logistics are neither planned for or thought through during the war game.

OPORD/FRAGO: This is often a tedious clerical task that slows the process of order dissemination. An AI driven system could collate logistical and operational information. The logistical information is often hard to capture or is inaccurate.

Some additional suggestions by CPT Garcia in using automation:

1. Produce a preparation planning chart that is like a time line of critical events. This would tie in doctrine with tasks identified for accomplishment on the battlefield. An example is an operation for a brigade to seize an objective. However, an unfordable river is between the friendly force and the objective. It is now necessary to conduct a river crossing. The AI system would be an honest broker for things such as engineer support, fire support, air defense coverage, etc. It would work hard to make sure none of the pieces were left out of the development of the operational plan.

2. Staffs do not execute the command estimate well because they only practice it during field training. An AI system would be used for all staff actions, both administrative and tactical, to allow the staff to develop and maintain proficiency in the use of the command estimate process.

3. An AI system would standardize the commander's planning guidance. It must address the battlefield operating systems (BOS) in additional to situationally dependent items.

4. A question that concerns many combat arms officers is what happens if the computer fails? How can the commander or staff go to the manual system, then at

some future point, bring the AI system back on-line? If automation is to be used in the command estimate, these questions must be answered.

5. Much time is wasted assembling the staff or conducting the planning of an operation while some of the staff members are absent. An AI based system must be able to process on a distributed architecture in a real-time mode.

The observations furnished by CPT Garcia were documented with CALL Full Observation Reports from the Army Lessons Learned Management Information System (ALLMIS). These identified operational areas in the command estimate process that could be assisted with the use of rule-based expert systems.

Jon Fallesen, Ph.D., Army Research Institute

DR. Fallesen is a behavioral psychologist with the Fort Leavenworth Field Office of the Army Research Institute (ARI). He has been studying the human dimension of command and control. This interview was conducted on 19 January 1990.[3] The focus of this interview was the findings of ARI in the execution of the command estimate.

A surprising observation made by DR. Fallesen was that the command estimate is often not always used in the field due the following reasons:

Time constraints: Staffs cannot do everything that is prescribed by doctrine or procedure in the time available.

Cognitive biases: Human adopted strategies can be suboptimal (will not accomplish the assigned mission),

Information use: Commanders and staffs do not actively seek or disseminate information due to the threat of information overload.

Information uncertainty: There is a large degree of uncertainty in tactical information. Consequently, the information received by commanders and staffs is often mistrusted. This causes time and effort to be wasted by verifying the information or waiting for other information to corroborate the uncertain information.

Over-confidence: Commanders and staffs often suffer from over estimating the abilities or capabilities of their forces. This causes implementation of poorly conceived and synchronized plans. It also results in the development of few contingencies.

Experience: A lack of experience on the part of commanders and staffs can result in less than optimal tactical judgments.

Management of process: Staffs often suffer from poor group dynamics. This causes an incomplete decision making process in which issues are resolved as the last option discussed.

"Option" definition: Commanders and staffs frequently do not distinguish between multiple COAs. The result is that only one COA is developed.

Scope: Different decision making models apply for tactical versus other problems. The military decision making process may not be applicable in all situations.

Decision analysis: The ability to make correct decisions is highly situation dependent. Some commanders and staffs will consistently make good decisions; others will not.

This interview produced hard scientific evidence of areas in the command estimate that do not perform well due to lack of time, inefficient information management, or human experience factors. The use of these observations assisted in identifying areas that could be improved with rule-based expert systems.

LIEUTENANT COLONEL STRAND, Future Battle Lab

LTC Robert A. Strand is the director of the Combined Arms Center (CAC) Future Battle Lab at Fort Leavenworth, KS. This interview was conducted on 9 March 1990.[3] The focus of this interview was the process of command and control and how automation can assist it.

LTC Strand stated three primary reasons why commander's and staffs do not follow the command estimate are:

1. Shortage of time.

2. Lack of familiarity with the process.

3. The command estimate, as defined by ST 100-9, may not apply to the particular tactical situation.

The G3/S3 is the staff officer who takes all the various statuses and aggregates them. These include the combat, combat support, and combat service support statuses. The G3/S3 performs the synthesis of this information and advises the commander on operational options. Often, it is the job of the chief of staff to do this, but it is the G3/S3 who has the information and is in the best position to assess it and make a recommendation.

The G3/S3 should have the capability to go into the automated command and control system and selectively retrieve information without having to interpret volumes of data to get the critical information.

Most commanders base their decisions on a small set of data elements. The particular data elements do not change from operation to operation. However, dependent upon the situation, the priority in which the commander may need the data elements may change. In most cases, the information that the commander needs is already generated or being maintained on an automated system somewhere within the command. A system is needed that can retrieve

this information and provide it to the commander in a timely fashion so he can act on that information and make informed decisions.

LTC Strand stated that we do not want to drown the commander with information, but we have to provide him with the most recent and most correct data so he can make the best and most informed decisions. I introduced the term of executive information systems (EIS) that are found in industry. LTC Strand stated that the capabilities of an EIS are the same that are needed in an automated command and control system.

A capability demonstrated by the AirLand Battle Management system (ALBM) was that rule-based systems can array forces. This has the potential for allowing the commander, or staff officer conducting the war game, the ability to do multiple what-ifs for a course of action. It will let you mix and match forces and how they are disposed on the battlefield.

War gaming can highlight areas of concern for the commander. It can help to pinpoint the elements of essential information that the commander needs in a tactical situation. War gaming can also help to identify critical assumptions.

A rule-based expert system assisting the command estimate can perform as an automated checklist to make sure doctrine is adhered to and all the elements that are

available to a military force have been included and synchronized into the overall scheme or plan.

LIEUTENANT COLONEL TICHENOR, Center for Army Tactics

LTC Tichenor is an instructor in the Center for Army Tactics (CTAC) at the Command and General Staff College. He served as one of the project officers for the development of ALBM and was a command and control subject matter expert for the rule and knowledge base engineering during project implementation. This interview was conducted on 22 January 1990.[4] The focus of the interview was his experience of ALBM and professional observations of the command estimate in practice.

With respect to his experiences in the development and implementation of ALBM, he stated that it had a tremendously large rule base. It included the rules of war, tenets of AirLand Battle, and a lot of other rules that are often in conflict with each other or with each segment of the battlefield (rear, deep, close). An interesting point is that it took a lot of time for the knowledge engineers to establish the rule base. This was a recursive process where the knowledge engineers had to keep interviewing the subject matter experts (SMEs) in very minute detail.

A salient point is that ALBM was not intended to provide leadership. Even when given a system such as ALBM, the commander is still responsible for everything

the unit does or fails to do. The ultimate decision of any action rests with the commander who must make the determination of whether or not to implement the solutions provided by ALBM.

The focus of ALBM should be the plans officer at division level. ALBM should replicate the manual process in case the equipment fails or reaches some point where human intervention is necessary. If the automated system is not parallel to the manual system, different solutions to common problems will be generated. This will not allow for an easy transition to or from human interaction.

LTC Tichenor felt that the biggest contribution a system like ALBM can make is that it can give a doctrinally correct aspect to an operation. It can also provide historical perspectives.

LTC Tichenor's observations on command estimate were based on extensive field experience in a wide variety of staff positions. He stated a major caveat to the command estimate process is that it was designed for the Fort Leavenworth academic environment and not necessarily for the battlefield. However, it's the best methodology the Army has and it does work as long as time is available. He does not foresee any changes to the command estimate process in the foreseeable future because it is the best system available.

Problems develop when the command estimate is performed under stress or time compression. Its strong point is the ability of staffs and commanders to synthesize phases of it based on experience and comfort levels.

An interesting point is that LTC Tichenor stated that commanders need executive information systems (EIS) to let them see the important trends (trend analysis) and manage by exception. Such systems would give them access to the five or six things that they need to know. These can be defined as the commander's information requirements.

MAJOR JOHN KELLY, Center for Army Tactics

MAJ John Kelly is a tactics instructor in the Center for Army Tactics (CTAC) in the Command and General Staff College. This interview was conducted on 24 January 1990.[8] The focus of this interview was MAJ Kelly's observations of the execution of the command estimate in both academic and field environments.

MAJ Kelly stated that there is a wide disparity of quality in the performance of the command estimate. When asked if he could differentiate between good and bad performance, he stated that the units and staffs who execute the command estimate well have several common traits:

1. Know the commander's intent.

2. Know the commander's information requirements.

3. Have a staff orchestrator.

The commander's intent is a key component in the command estimate. In units that perform poorly, the commander's intent is often not specific and is not disseminated well. The result is that the staff and subordinates do not understand the commander's intent and do not plan accordingly.

There are two methods of conveying the commander's intent. It can be either oral/written or as a graphic. The most effective method of having it understood is a combination of the two.

The command estimate is time dependent. There needs to be improvement in the analysis of available time and how to best use it. A major problem is that no one is designated as the time manager for planning. There needs to be someone to orchestrate the events.

An effective tool to manage time and integrate the BOS is the synchronization matrix. It is imperative that it give visibility of the time line, BOS, and sub-units. This information is normally in graphic form. One of the tasks of the synchronization matrix is the integration of the BOS. However, this is an extremely complex exercise and often exceeds the ability of the staff to properly use

all available assets to the fullest potential. Help is needed with prioritization and consultancy. This is an area where AI can perform with great utility.

Information management from higher and adjacent organizations is often poor. The commander is given enough, or more than enough, information. But it is normally old or overcome by events. What the commander is not provided is analysis of this information. Good analysis is a time consuming process that normally produces results too late in the planning process to be of value to the commander and staff. Additionally, outgoing information in the form of orders is often incomplete and does not precisely convey the commander's intent.

A large portion of the command estimate is based on the experience and judgement of the commander. This is hard to make into a set of rules that can be followed by a machine. For a system to be used in the field, it must be as painless as possible and provide the commander a tool, not a yoke.

The Intelligence Preparation of the Battlefield (IPB) is performed in isolation by the G2 and is not integrated into the G3's operation. The IPB should be continuous, with some system available to orchestrate its execution to mesh with the command estimate being performed by the remainder of the staff. A tremendous use

of AI could be to inform the staff when there is a difference between doctrinal/situational templating and ground truth of the enemy.

When it is determined that not enough time is available to perform the command estimate, the abbreviated process must be initiated. This is not a curtailment of the formal process. In the abbreviated command estimate, all the steps need to be done. What is needed is assistance in showing what steps or processes can be shortened.

MAJOR ED KASTER, Center for Army Tactics

MAJ Kaster is an automated command and control systems instructor in the Center for Tactics (CTAC) at the Command and General Staff College. This interview was conducted on 4 January 1990.[6] The focus of this interview was the Maneuver Control System (MCS) and automated command and control systems.

A primary source of information was an after action report (AAR) containing the observations of a MCS class conducted at CGSC.[7] While MCS is an exceptional hardware suite, the software does not give a tremendous amount of functionality. It is an acceptable means of sending free text messages on the battlefield. Manipulated by a well trained operator, the MCS data base functions can provide large volumes of tabulated data.

While the E-mail and database capabilities are definitely valuable assets, by themselves they do not significantly help the commander see and fight the battle. The four other functions of planning, coordinating, directing, and controlling must also be included within the system. To support these functions the system must have a functional graphics system and the current graphics capability is totally unacceptable. This leaves us with a computerized message center and logistic update system, not a maneuver control system.

Future software revisions will work to add more functionality to MCS. However, this is dependent upon how well the Army voices requirements.

Although MCS appears to provide a satisfactory method of putting information into the system, there are current problems in transferring and sorting data and displaying intelligent information. So far, automation appears to have created problems with information overload. With the exception of some pie charts, MCS provides data, not information. An AI tool may be helpful in sorting out what is important and needs to be immediately brought to the commander's attention. It may also be able to determine what can be stored away until it is needed, and what is 'junk mail' that needs to be purged from the system.

MCS must be able to do three things within all of its functions. These are the same functions expected of a civilian executive level computer support system.

1. It must provide a top-down high speed review of operational information.

2. It must show trend analysis.

3. It must provide exception reporting.

MAJOR (Ph.D.) RICHBOURG, West Point AI Lab

MAJ Robert F. Richbourg, Ph.D., is a research scientist in the office of artificial intelligence, Department of Geography and Computer Science, United States Military Academy. This was the only germane interview conducted via electronic mail (E-Mail) on the *Defense Data Network (DDN)*. I spoke with him informally at CGSC in December 1989. He directed me to send him some of my questions on DDN and he would respond. The focus of the interview was to establish the limits of rule-based expert systems in the command estimate. The following is a summation of the interview:

When asked if he felt if artificial intelligence should be used in military command and control, MAJ Richbourg responded that we should try to make use of any applicable advanced technology to support command and control. AI does include many well-defined techniques that are applicable. However, current AI technology can not completely replace the man in the decision cycle. It

can augment the abilities of commanders and staffs by prompting for key considerations, filtering information, providing "what-if" simulations, etc.

When discussing the architecture of a rule-based expert command and control system MAJ Richbourg stated that such a should be embedded, if possible, within other maneuver control systems. This system should also be distributed to allow input from the entire staff. Ideally, the system should support staff decisions as well as those made by the commander.

Operational systems can be developed to perform as assists to the human, or in some well-defined problem domains, to perform the decision tasks. The distinction is based on the size and type of problem. As a trivial example, a rule-based expert system could easily replace the man in the checkbook balancing decision cycle).

MAJ Richbourg stated that the Department of Defense standard computer language, Ada, can be used to develop AI based command and control systems?

The topic of the complexity in finding and using knowledge engineers for establishing tactical decision aids was discussed. MAJ Richbourg stated that for small problems, the user of the system can also be the knowledge engineer. For more complex problem areas (such as maneuver planning), reliance on a trained knowledge engineer is a much better choice. Complex systems usually

require complex interactions within the knowledge-base and the management of these complexities is best left to trained computer scientists. However, regardless of the complexity of the problem, the knowledge-base should be modular, making changes less difficult.

Some of the shortcomings of expert system (ES) technology were briefly noted by MAJ Richbourg:

1. These systems do not have intuition.
2. They do not learn.
3. They are not creative.
4. They have a narrow view of the problem.
5. They can not apply common sense reasoning.
6. They are poor at interpreting sensory data.

When tasks require these traits, they are best performed by humans, who might be assisted by rule-based expert systems. There are many things that can be done well by such a system. However, the crucial task is to decide where the technology is most applicable and then implement it.

APPENDIX B END NOTES

[1]CPT Anthony Garcia, 12 January 1990, CATA, Center for Army Lessons Learned, Fort Leavenworth, KS.

[2]Interview, DR. Jon Fallesen, 2 February 1990, US Army Research Institute Field Team, Fort Leavenworth, KS.

[3]LTC John A. Strand, 6 February 1990, CAC, Future Battle Lab, Fort Leavenworth KS.

[4]LTC Arthur H. Tichenor, 22 January 1990, CGSC, Center for Tactics, Fort Leavenworth, KS.

[5]MAJ John Kelly, 18 January 1990, CGSC, Center for Tactics, Fort Leavenworth, KS.

[6]Memorandum, ATZL-SWT-C (CTAC) to Commander, USA Combined Arms Center, Subject: After Action Report, Advanced Command and Control Elective, A399. (2 June 1989): (Cited hereafter as MCS AAR).

[7]MAJ Robert F. Richbourg, 4 January 1990, Department of Geography and Computer Science, West Point, NY.

APPENDIX C

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GLOSSARY

Army Lessons Learned Management Information System (ALLMIS): A data base of observations made by the Combined Arms Training Activity (CATA) Center for Army Lessons Learned (CALL). These observations document training and performance at the NTC and during real-world operations such as Urgent Fury and Just Cause.

Army Research Institute (ARI) for the Behavioral and Social Sciences: An Army activity that performs research and analysis of behavioral sciences.

ATCCS: Army Tactical Command and Control System. The command and control system utilized by all tactical echelons up through corps. ATCCS includes the organization, facilities, and procedures through which the commander plans, directs, controls, and coordinates operations.[1]

Artificial Intelligence (AI): A discipline of computer science dedicated to the development of computational machines that exhibit intelligent behavior and that approximates the human reasoning process in decision making.[2] AI systems normally are based on series of rules

or procedures for a specific situation or problem. The solution to the problem is found by a backward chaining process that starts with the desired solution and sequentially works towards the current state. AI's largest difference from human reasoning is that it does not have intuition.

Background Mode: An operation in an computer system that occurs regardless of what the current process in the system is. An example would be a communications monitor that will signal a warning to a staff officer anytime a particular unit identification is received in a hardcopy message. This background operation will be performed even when the computer system is involved in printing a report or sorting a data base.

Battlefield Information System: An automated system to handle the unique requirements a commander or staff officer needs to harvest, process, and disseminate information in a tactical battlefield environment.

Battlefield Operating System (BOS): The major functions occurring on the battlefield, each consisting of systems employed to successfully execute operations by the total Army. The seven BOS are: maneuver, fire support, air defense, command and control, intelligence, mobility and survivability, and combat service support.[3]

Button: In a hypertext document, a physical tag that connects a word or phrase in the document to a similiar word or phrase in another document. These buttons are created on an individual basis to ensure that a specific linkage is made between the designated words or phrases.

Center for Army Lessons Learned (CALL): A component of the Combined Arms Training Activity, Fort Leavenworth, KS. CALL performs historical analysis of training and performance at the NTC and during real-world operations.

Center for Army Tactics (CTAC): The Army's focal point for tactics doctrine and instruction. The center provides doctrinally sound tactics expertise to assure coherence among doctrine, organizational concepts, weapons concepts, and training.

Combined Arms Research Library (CARL): The research library located and operated by the US Army Combined Arms Center as an adjunct to the Command and General Staff College, Fort Leavenworth, KS.

Command and Control (C2): The process through which the activities of military forces are directed, coordinated, and controlled to accomplish the mission. This process encompasses the personnel, equipment, communications, facilities, and procedures necessary to gather and analyze information, to plan tasks, to issue instructions, and to supervise the execution of operations.[4]

Command and Control System: The facilities, equipment, communications, procedures, and personnel essential to a commander for planning, directing, and collecting operations of assigned forces pursuant to the mission assigned.[5]

Command estimate: The process used by military commanders and their staff that focuses on essential facts and necessary assumptions to make decisions that will lead to success on the battlefield.[6]

Commander's Intent: The commander's vision of how the battle will be fought. It is the commander's expression of how the battle is to be fought and what is to be accomplished.[7]

Constraint: Limitations placed on the command by the higher commander. Constraints restrict the freedom of action a headquarters has for planning a mission. Constraints are those things a planning headquarters are required to do.[8]

Consultant Expert System: Expert systems that can provide correct doctrine and procedures in areas that commanders and staffs may not be technically knowlegeable in.

Expert Systems: A sub-field of artificial intelligence in which the computer programs follow rules established by a human expert in a specific problem domain.[9]

Estimate of the situation: In the military decision making process, the collection and analysis of relevant information for developing, within the time limits and available information, the most effective solution to a problem.[10]

Data Base: A collection of interrelated data stored together with a minimum of redundancy to serve multiple applications.

Data Flow: A conduit through which packets of information of known composition flow.[11]

Data Flow Diagram (DFD): A network representation of a system portrayed in its component parts.[12]

Data Store: In a data flow diagram (DFD), a data stores is where information is kept or deposited. This is often a temporary store of information as it awaits processing by another part of the system.[13]

Defense Data Network (DDN): A packet switched data network owned and operated by DOD for use by E-Mail.

Defense Technical Information Center (DTIC): An information resource center operated by the Department of Defense to manage and maintain militarily significant technical information.

Electronic Mail (E-Mail): A system providing data communications between two or more computers.

Estimate of the Situation: A systematic military decision-making process that is typified by considering significant facts and assumptions to arrive at a recommendation on how to best use available resources to resolve a problem or mission.

Executive Information System (EIS): A family of civilian software applications that accesses, creates, or delivers high-level information to nontechnical executive decision makers.

FRAGO: Fragmentary order. An abbreviated form of an operations order (OPORD) used to make changes in missions to units and to inform them of changes in tactical situations.[14]

Hypertext: A method of linking information by associated meaning as opposed to traditional numeric or alphabetic schemes. Documents become data bases where any word or phrase can be used for sorting or searching operations.

Knowledge engineer: An AI technologist who performs in depth interviews with subject matter experts to extract the heuristics and factual rules of the domain knowledge to be encoded into the expert system knowledge base.[15]

Maneuver Control System (MCS): A command and control system that focuses on the tactical execution of war. Currently, MCS is in the form of an automated system based on a collection of data bases and attendant communications facilities to disseminate information.

Normalize: The process of making a term or graphic conform to doctrinal correctness. This is important to insure that the commander's image of an operation is conveyed to subordinates in exacting clarity.

OPLAN: A plan for a military operation. It covers a single operation or a series of connected operations to be carried out simultaneously or in succession.[16]

OPORD: A directive issued by a commander to subordinate commanders for effecting the coordinated execution of an operation. It is normally the tactical orders given to a unit.[17]

Rule-based Expert System: An artificial intelligence system that uses a base of rules defined by a human expert to solve a clearly defined problem.

Sink: In a data flow diagram (DFD), a sink is the system interface with the external world. This is where information leaves the system. In the command estimate, this is normally a FRAGO, OPORD, warning order, or a graphic overlay.[18]

Source: In a data flow diagram (DFD), a source is the system interface with the external world. This is where information enters the system. This is normally in the form of an order from a higher headquarters or a higher commander's intent or guidance.[19]

Subject Matter Expert (SME): A human expert in a particular field or problem domain from which the procedures for solving a particular problem are taken.

Synchronization Matrix: A graphical tool used by staff planners to orchestrate battlefield operating system resources into military operations.

Systems Analysis: The methodical investigation and study of a data flow problem with the view toward improving that flow in terms of maximizing cost benefits, speeding up results, and reducing errors.[20]

War Game: A method of comparing courses of action in the command estimate. Used primarily by the G3/S3, it is a conscious attempt to visualize the flow of battle, given friendly and enemy dispositions, enemy assets, possible enemy courses of action, and a defined area of terrain.[21]

Warning Order: A preliminary notice of an action or order that is to follow. Usually issued as a brief oral or written message, it is designed to give subordinates time to make necessary plans and preparations.[22]

APPENDIX C END NOTES

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[2]Paul E. Lehner, Artificial Intelligence and National Defense: Opportunity and challenge (1989): xi.

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[5]Ibid: B-4.

[6]ST 100-9, (1989): 1-2.

[7]US Army, Field Manual 101-5-1, Operational Terms and Symbols. (1985): 1-17.

[8]US Army, Student Text 100-9, The Command Estimate. (1989): 2-6.

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[13]Tom DeMarco, Concise Notes on Software Engineering (1979): 5.

[14]FM 101-5-1 (1985): 1-34.

[15]Lehner, 15.

[16]FM 101-5-1 (1985): 1-53.

[17]Ibid.

[18]Control Data Corporation, Defining Software Requirements (1985): 3-3.

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